FUNGOUS DISEASES OF FRUIT-TREES

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FUNGOUS DISEASES OF FRUIT-TREES

FUNGOUS DISEASES OF FRUIT-TREES IN NEW ZEALAND

AND THEIR

REMEDIAL TREATMENT

BY

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SPRAY FORMULAE
IN COLLABORATION WITH
THE DIRECTOR, ASSISTANT DIRECTOR, AND ORCHARD
INSTRUCTORS, HORTICULTURE DIVISION,
DEPARTMENT OF AGRICULTURE.

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THIS BOOK IS
RESPECTFULLY DEDICATED TO

DANIEL McALPINE

LATE VEGETABLE PATHOLOGIST,
DEPARTMENT OF AGRICULTURE, MELBOURNE, VICTORIA,
WHOSE PIONEER RESEARCHES INTO THE FUNGI
OF AUSTRALIA
HAVE MADE ITS COMPLETION POSSIBLE.

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PREFACE

THIS publication is the outcome of five years' continuous study—both in the field and in the laboratory—of the Fungous Diseases attacking the commercial orchards of New Zealand.

In the majority of cases it has been found necessary to work out, in the laboratory, the life-histories of the fungi discussed herein. Wherever spray treatments are given these have been based upon actual experiments carried out in the orchards by the Orchard Instructors of the Horticulture Division, under their Director, MR. J. A. CAMPBELL. Hence in this publication no information regarding spray treatment is given, unless the treatment has been put successfully into operation. Many of these diseases have been dealt with previously in the *New Zealand Journal of Agriculture*, and certain information has been given from time to time regarding them at the numerous lectures given by the author before the various Fruitgrowers' Associations throughout New Zealand. This work is published to meet the urgent demand expressed at these meetings, and the scope and arrangement are dictated largely by suggestions of growers. These have been followed herein, so it may be claimed that the whole work has been arranged in accordance with suggestions from the orchardists themselves.

The book is divided into two sections, the first dealing with general matters relating to hosts, fungi, bacteria and control measures; the second with those specific organisms causing the various diseases with which orchardists have to contend. In the first part is a chapter dealing with the botany of a living tree; this has been written at the request of many growers, who find this necessary information difficult to obtain owing to the paucity of literature dealing with this subject in an elemental manner.

The part dealing with the chemistry of sprays has been treated in as elemental a manner as possible, the aim being to bring out only those facts of practical significance to the orchardist.

Technical terminology has been excluded as far as is possible without allowing confusion to creep into the text, but, when dealing with such a specialised branch of botany as plant pathology, it is impossible to avoid the use of a certain number of technical terms. When these have been used in the text, no attempt is there made to explain them, but the reader will find in the beginning of the book a glossary fully explaining the meaning of each term.

The maximum number of illustrations has been used to aid the orchardist in determining any disease with which his trees are infected; further to facilitate determination, the section dealing with specific diseases is divided firstly into—

A. Pome fruits (apples, medlars, pears, quinces).
B. Stone fruits (almonds, apricots, cherries, peaches, plums).
C. Citrus fruits (citrons, limes, lemons, mandarins, oranges, pomelos).

At the beginning of the list of diseases attacking each group of hosts is a symptomatic key, which should assist in the determination of any particular disease. Finally, the diseases themselves—in order to facilitate discussion in the text, and avoid undue repetition—are subdivided into three groups:—

a. Fungous diseases.
b. Bacterial diseases.
c. Physiological diseases.

As the botanical names of the organisms causing disease are occasionally changed, the author has endeavoured to standardise the common names used for the diseases they cause. In all cases names in common use have been retained.

When any disease attacks members of more than one host-group, it is dealt with in detail under that group individuals of which are more severely and commonly attacked, and cross references are given under other groups.

Finally, an extensive index is appended. In this synonyms both of common and scientific names, are listed, so that the orchardist readily may find any disease he seeks, even although he may know it under some name not recognised in this book.

The manuscript of this book was completed by the end of March, 1924. In November it was accepted for publication by the Board of Directors of the New Zealand Fruitgrowers' Federation, Ltd. Such action on their part well illustrates the progressive nature of the policy of the Federation.

The author expresses his appreciation of assistance rendered by the following:—

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Thanks are tendered to those numerous overseas mycologists who have so generously forwarded separates of their publications, and in many cases, specimens of various diseases; and finally to the blockmakers and compositors of the staff of the Brett Printing and Publishing Co., Ltd., Auckland, engaged in the preparation of this work for the fine results they have attained. The compositors' instructions have been to "follow copy," so that where errors in style, etc., occur they in no way reflect upon the craftsmanship of these gentlemen. It is customary for the author to label all typographic and other errors as "printer's errors," but the staff of Messrs. Brett and Co. have not left the author even this subterfuge to fall back upon. The author may with justification claim that the blockmakers have obtained the maximum results from the photographs submitted; where there is any falling off from the high standard maintained, it is due to poor photographs only.

G. H. Cunningham.

Biological Laboratory,
Wellington, New Zealand,
March, 1925.

GLOSSARY.

abstriction: the cutting off of spores on portions of growing hyphae by septa, and the detachment by disappearance of connecting zone.

acervulus: a cushion-like mycelial stroma, giving rise to conidiophores arranged in palisade fashion, from the apices of which are produced conidia.

acrogenous: growing at the apex.

adpressed: closely and completely pressed against.

aecidial stage: the stage in the life-history of the rust fungi in which aecidiospores are produced.

aecidiospore: a spore form of the rust fungi; the spores are produced within cup-shaped peridia (Fig. 134).

aecidium: the first spore stage occurring in the life-cycle of certain rust fungi; consisting of aecidiospores together with an enclosing peridium (Fig. 134).

anther: that portion of a stamen which contains the pollen (Fig. 9, *d*.).

apothecium: an ascus-bearing structure which is open and exposed at maturity (Fig. 110).

ascigerous stage: the stage in the life-cycle of an ascomycetous fungus in which ascospores are produced.

Ascomycetes: the name of one of the main classes of fungi, characterised by the production of spores in asci.

ascospore: a spore borne within an ascus (Fig. 111).

ascus: a large cell in the fructification of an ascomycetous fungus within which ascospores are developed (Fig. 111).

Basidiomycetes: the name of one of the main classes of fungi, characterised by the production of spores borne on basidia.

basidiospore: a spore borne on a basidium (Fig. 151).

basidium: a large cell in the fructification of a basidiomycetous fungus which bears external spores (Fig. 151, *s*.).

callus: the tissue produced by a plant in response to a wound stimulus (also applied to a special deposit on the sieve plates).

calycine sinus: the open passage from the calyx end to the centre of the ovary characteristic of certain varieties of apple fruits (Fig 11).

calyx: the outermost of the floral envelopes (Fig. 9).

cambium: a layer of nascent tissue between the xylem and phloem which adds elements to both (Fig. 3).

carbohydrates: compounds, such as cellulose, starch, sugars, etc., formed by plants by the combination of carbon with the elements of water.

carpel: a simple pistil or element of a compound pistil (Fig. 9, *b.*).

cc. = cubic centimetre (see p. 99).

cell: an independent unit of protoplasm; in the broad sense the term also includes the enclosing wall of cellulose.

cellulose: a carbohydrate, the chief constituent of the plant cell wall.

chlamydospore: a spore formed within a hypha, or portion thereof, possessing a thick suberised wall (Fig. 52).

chlorophyll: the green colouring matter of plants.

circumscissile: splitting equatorially.

cm. = centimetre—2-5th of one inch.

conidiophore: a sporophore bearing a conidium = pycnidiophore (Fig. 108, *con.*).

conidium: a propogative cell or spore, asexually produced, borne on a conidiophore; used herein in place of "spore," "pycnospore," "pycnidiospore" (Fig. 58).

coremium: a columnar bundle of loosely interwoven conidiophores.

coriaceous: leathery.

corolla: the petals of a flower (Fig. 9).

cortex: herein this term is applied to all plant tissues lying between the epidermis or bark and the cambium (Fig. 3).

cuticle: a non-cellular layer lying outside the epidermis, composed of a waxy substance secreted by the protoplast.

cutin: a waxy substance secreted by plants which is impervious to liquids and gases.

cytase: an enzyme found in germinating seeds which hydrolyses cellulose.

cytoplasm: the general protoplasm of the cell.

dehiscence: the mode of opening of a spore- or seed-bearing receptacle.

diffusion: the mixing, or dispersion through a tissue, of liquids or gases.

distal: located furthest from the main axis or base.

drupe: a fruit in which the pericarp is differentiated into fleshy or leathery exocarp and a hard endocarp (the stone) enclosing the seed.

ectoparasite: a parasite which remains on the exterior of the host, sending only its haustoria within the host cells.

ectoplasm: a delicate superficial membrane of the cytoplasm.

endemic: confined to a given region, i.e., New Zealand.

endocarp: the inner layer of a pericarp.

endoparasite: a parasite which lives and develops within the host tissues.

enzyme: an unorganised or soluble ferment.

epicarp: the external layer of the pericarp of a fruit.

epidermis: the outer cellular layer in plants.

evanescent: soon disappearing.

excretion: the action by which any substance is rejected from an organism.

ferment: a substance which produces chemical changes without itself taking part therein.

filiform: thread-like.

flaccid: limp or flabby, a condition due to deficiency of liquid cell-contents (converse of turgid).

flagellum: a whip-like process of the protoplasm of a free cell (Fig. 165, *b*.).

fructification: any plant structure specialised for the production of spores or seeds.

fusiform: spindle-shaped.

globose: spherical.

haustorium: special branch of a hypha for abstraction of food substances from the host.

heteroecious: passing stages in the life-history on different hosts.

host: a plant or animal which nourishes a parasite.

hyaline: colourless or translucent; glassy.

hymenium: the sporiferous layer of the fructification of certain fungi.

hypha: a cylindric, thread-like chain of cells; the primal element of fungous tissue (Fig. 72, *m.*).

hypodermis: the cellular layer beneath the epidermis.

lamina: the blade or expanded part of a leaf.

lenticel: a porous part in the bark or epidermis adapted for respiration of the underlying tissues.

lesion: a focus of disease.

loculus: a subdivision or chamber of a fructification.

medulla: the pith.

medullary ray: a plate of cellular tissue radiating from the pith or from an annual ring to the cortex.

mesocarp: the middle layer of a pericarp.

mesophyll: the interior chlorophyll-bearing tissue of a leaf.

middle lamella: the membrane or primary septum between any two cells.

m. = metre—39.37 inches.

mm. = millemetre—1-25th of one inch.

mycelium: a collective term used for the vegetative part of a fungus composed of hyphae.

necrosed: in a wide sense used for all dead tissues on a living plant; usually restricted to any cankered condition on a living plant.

nucleus: a specialised portion of the protoplasm of a cell.

occlusion: the process by which wounded surfaces are covered with a growth of callus.

olivaceous: olive coloured.

osmosis: diffusion of liquids through a membrane.

ostiolum: an opening or pore (Fig. 57, *os.*).

ovule: the young seed in the ovary (Fig. 8, B., *b.*)

palisade parenchyma: a layer of elongated cells of the mesophyll arranged with their long axes perpendicular to and just below the epidermis of a leaf (Fig. 145, *p.*).

papillate: having a small superficial protuberance; nipple-like.

paraphyses: sterile filaments occurring in the hymenium of certain fungi.

parasite: an organism living at the expense of another living organism.

parenchyma: more or less unspecialised cellular tissue.

pathogenic: causing disease.

pedicel: the stalk of the flower or fruit (Fig. 9, *c.*).

pericarp: the wall of the fructified ovary.

pericycle: the outermost zone of cells of the stele.

peridium: the receptacle enclosing the aecidiospores (Fig. 134, *p.*).

perithecium: a flask-shaped structure in ascomycetous fungi within which the asci are borne (Fig. 45).

petal: a leaf-like, usually coloured part of a flower (Fig. 9, *f.*).

petiole: the stalk of a leaf.

phellogen: nascent tissue capable of producing cork cells.

phloem: the bast elements in a vascular bundle, through which elaborated foods are conducted (Fig. 3).

photosynthesis: the formation of complete carbon compounds from simpler ones under the influence of light.

pistil: the female organ of a flower, consisting when complete of ovary, style, and stigma (Fig. 8).

plastid: a protoplasmic granule in an active cell differentiated as a centre of chemical or vital activity.

polymorphic: with several or various forms; variable as to habit.

proteid: a general name for albumenoids; complex substances which form the chemical basis of living protoplasm.

protoplast: the unit of protoplasm capable of individual action; the living contents of the cell.

proximal: located nearest the main axis or base.

pulvinate: cushion-shaped.

pycnidium: an enclosed structure in certain fungi within which conidia are borne on conidiophores (Fig. 57).

saprophyte: an organism living on dead organic material.

sclerotium: a compact mass of hyphae, capable of remaining quiescent for an indefinite period.

secretion: the action by which any substance is formed by an organism to fulfil a definite function.

sepal: a segment of the calyx or outer whorl of a flower (Fig. 9, *g.*).

septate: divided into partitions by septa.

sessile: without a stalk.

sieve tube: a long, articulated tube whose segments communicate by means of sieve plates. Sieve tubes constitute the channels in the phloem for the transfer of elaborated sap (Fig. 3).

solute: any substance dissolved in a liquid.

sporangium: an exposed sac endogenously producing conidia or zoospores (Fig. 165, A).

spore: a single cell which becomes free and is capable of developing into a new plant.

sporodochium: the spore-producing portion of certain fungi, consisting of a closely woven mycelial stroma bearing conidiophores.

sporophore: a portion of a fungus specialised for spore production.

stamen: an element in a flower, consisting of anther and filament.

sterigma: the filament which connects a basidiospore with its parent basidium (Fig. 151).

stigma: that portion of the pistil of the flower which receives the pollen.

stoma: breathing pore or aperature in the epidermis of leaves, fruit, and young stems.

stroma: a closely woven, cushion-like mass of hyphae.

style: that portion of the pistil which connects the stigma with the ovary.

synthesis: the process of building up compound substances from their elements.

teleutospore: a spore form of the rust fungi (Fig. 136).

toxic: poisonous.

toxin: a poisonous substance produced by certain parasitic fungi and bacteria which injures or kills the host tissues.

tracheal tubes: water-conducting vessels in the xylem or wood of plants.

turgid: applied to cells distended by pressure of the contained liquid.

umbilicate: navel-like.

uredosorus: a term applied to a pustule or group of uredospores, together with their pedicels and accompanying paraphyses (Fig. 135).

uredospore: a spore form of the rust fungi (Fig. 136).

vascular bundle: a strand of tissue in plants containing phloem and xylem specialised for conduction of food materials and water (Fig. 3).

ventral: the lower surface; as opposed to dorsal.

viable: likely to live and grow.

xylem: the wood or tracheal elements in a vascular bundle (Fig 3).

zoospore: a conidium capable of independent movement. (Fig. 164, B).

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INTRODUCTION.

IN the early days of settlement in New Zealand the individual domestic orchard adequately catered for the fresh fruit requirement of the colony. The small orchard with its wide range of variety, was a regular adjunct to the kitchen garden of both the town and country dweller. Quantities of fruit far in excess of local requirements were produced, particularly in favourable seasons. Fruit-shops, even in the larger centres of population, were uncommon, and whatever trading was done in surplus fruit was largely in the nature of barter in connection with the grocery requirements of the individual family. So long as the majority of the people could produce fruit easily and cheaply, with comparatively little attention save that of pruning and a small measure of cultivation, no inducement was offering for the establishment of a fruit industry along commercial lines. It is probable that unless certain features had developed the domestic orchard would still be supplying the major quantity of locally consumed fruit. Three factors, however, have completely altered the significance of fruit-growing in New Zealand. All of them have tended to the elimination of the "backyard" orchard, and to its replacement by a highly technical and specialized profession that bids fair to stabilize finally into the most important of the minor agricultural occupations of the Dominion. The three factors that have led to the development of commercial fruit-growing on a basis of a specialized industry have been disease, increased local demand, and export possibilities.

The inadequacy of the domestic orchard to fulfil the growing demand soon made itself manifest. Diseases both of fungous and insect origin became rampant, and the production of marketable fruit steadily became increasingly difficult and precarious. The position in no way improved by an increase in acreage devoted to domestic orcharding, where fruit production remained a side-line, as new orchards to replace those rendered useless by disease soon in their turn became affected to the point of unprofitable production. The neglected, disease-permeated, domestic orchard was the conspicuous feature in the history of fruit-growing in the eighties of last century. The increasing demand for fresh fruit then led to the establishment of many more or less commercial orchards during this period, and the centreing of fruit production into definite localities. These varieties that experience had taught were most prone to disease were no longer planted, and so far as apples were concerned, reliance was placed on blight-proof stocks such as Northern

Spy. Many individual varieties were still made use of under the idea that some at least would withstand disease, but this method failed, and disease soon rendered the semi-commercial orchard as unprofitable as the domestic orchard, except in certain localities, such as Central Otago. Such was much the position of affairs on the establishment of the Department of Agriculture in 1892. The appointment of Mr. T. W. Kirk as Biologist in that year, marks the first step in the stabilizing of our present fruit industry. He early recognised that disease control was the essential factor in fruit production, and that the education of the fruit-grower along this line was imperative. Accordingly, in 1893, Mr. W. J. Palmer and Mr. J. C. Blackmore were appointed as Pomologists. Their duties were at that time almost entirely of an educational nature in disseminating information with regard to the chemical treatment of disease by means of various spraying compounds, of which bordeaux mixture, lime-salt-and-sulphur and paris green were the three main remedies.

The position was not encouraging—scales, codlin-moth, black-spot and pear-scab were rampant amongst apples and pears. The average quality of pip-fruit offered for sale would to-day be considered worthless for market purposes. Peach growing was quite unprofitable through the ravages of die-back and leaf-curl. The production of our three major fruits was thus in a deplorable condition, and the position was hardly any better with regard to other classes of fruit.

The decade between 1893 and 1903 was one of direct instruction to the grower on the preparation and use of sprays. Bordeaux mixture, lime-salt-and-sulphur and paris green remained the standard sprays that were tried out in many orchards, and by 1903 the majority of growers were convinced of the value of spraying. During the same period a general feeling arose that some method of compelling all growers to produce clean fruit was necessary, and the danger of neglected orchards and importation of diseased fruit as sources of infection of new areas was emphasized. In 1903 the *Orchard and Garden Pests Act,* afterwards termed the *Orchard and Garden Diseases Act,* was passed. This measure has been of the very greatest service in the development of the fruit industry, and the name of Kirk must always be associated with its promulgation. This Act, which in essence makes it a penal offence to allow certain specified diseases to be present in an orchard, has from the commencement been used as a lever for educating, rather than harassing the fruit-grower. In order to carry out its provisions, a gradually increasing number of Orchard Instructors has been employed, and the general adoption of our spraying methods, based both on foreign and local experience, can be traced to the extension work of these individuals. Many changes in the sprays and spraying methods of the nineties have gradually taken place. Winter spraying with lime-sulphur gave way to oil sprays, and arsenate of lead replaced paris green. Weak lime-sulphur sprays took the place of summer bordeaux spraying, owing to the damaging effects of the latter. The power sprayer increased the efficiency of all sprays used.

During the whole period that the Department of Agriculture has been established, pathological investigation of our major fruit diseases has been carried out, and the present system of disease management is almost wholly due to the work of the officers of the Department. During this period the Department has published many leaflets and bulletins on the control of individual diseases of the orchard, but up to the present no complete account of the major orchard diseases has appeared. Since 1919, when G. H. Cunningham took up his duties of Mycologist to the Department, he has been collecting material and conducting original investigations on the more important fungous diseases of the orchard. The present volume brings together the whole of present-day knowledge with regard to New Zealand orchard diseases, and will fulfil a demand that has been increasingly insistent from year to year.

In the past much of our disease control methods have been adaptations from the practices employed in other countries, rather than the actual working out of methods based on an accurate knowledge of the causal organism as it behaves under New Zealand conditions. The great value of the present volume rests on the fact that it links up control with the life-history of the organism studied under local conditions, and in this way represents an extremely notable contribution to the literature on plant pathology.

The losses experienced by disease are still extremely serious, but due rather to inefficient work on the part of the grower than to modern methods of control being at fault. In the past the grower has been well educated along the lines of spraying technique, but he is still often sadly deficient on the mycological side of his business. A good working knowledge of the behaviour of the diseases themselves is necessary in modern orcharding: without it successful orchard management is impossible. The permanent stability of our fruit industry rests very largely on the standard of knowledge of the individual and a better understanding of the diseases against which he has to contend is the first essential.

A. H. Cockayne,
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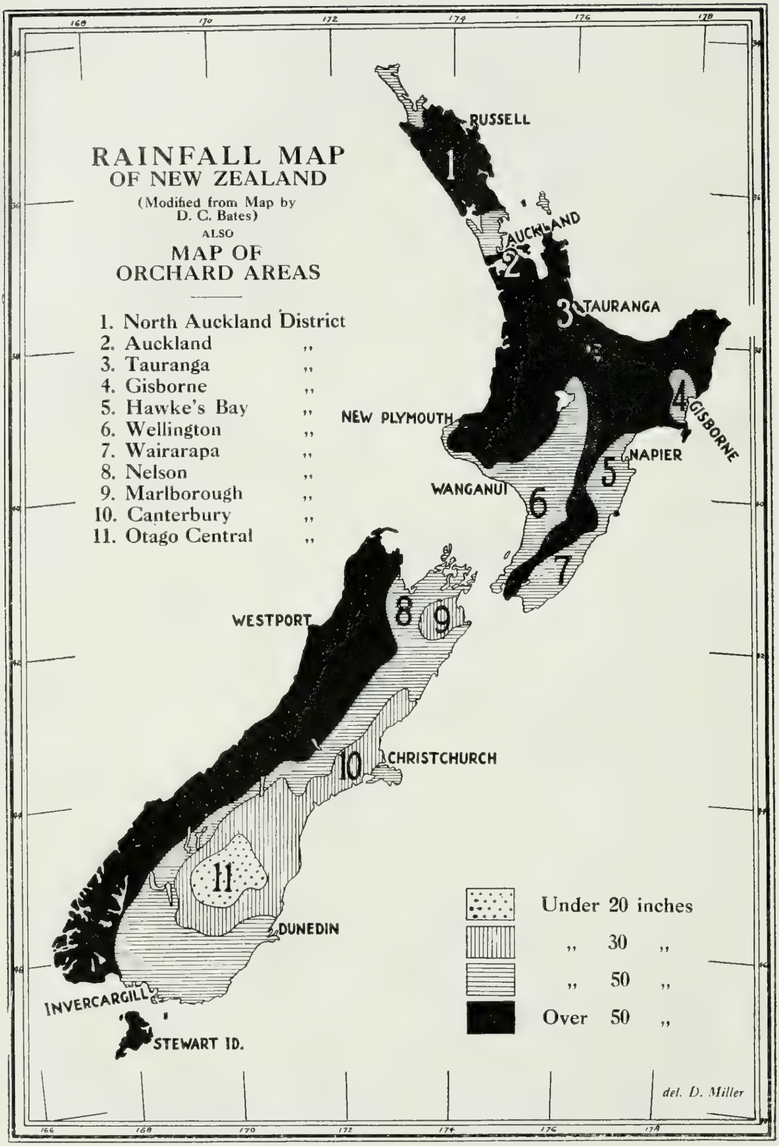

Fig. 1. RAINFALL MAP OF NEW ZEALAND
ALSO SHOWING ORCHARD AREAS.

Modified by D. Miller,
from Rainfall Map by D. C. Bates.

SECTION I.—GENERAL.

CHAPTER I.

GEOGRAPHY, CLIMATE AND FRUIT-GROWING AREAS OF NEW ZEALAND.

Rainfall Map; Geography; Climate; Map Showing Fruit-growing
Districts; Tables of Fruit-growing Areas;
Table of Fruit Exported.

GEOGRAPHY *(98)**

The Dominion of New Zealand consists of three islands: the North, South and Stewart Islands, lying between the 34° 6′ and 47° 20′ parallels of S. latitude, and the E. longitudinal meridians 166° and 179°. The North Island has an area of approximately 44,468 sq. km.; the South Island an area of 58,525 sq. km.; and Stewart Island an area of 664 sq. km.

New Zealand is far removed from any land mass, the nearest being the Australian Continent, 1,650 km. distant.

The land surface of both the main islands is much broken, and in parts mountainous, each being traversed by a practically continuous range, which has a considerable effect on rainfall.

CLIMATE.

The accompanying map (Fig. 1) gives a fairly accurate idea as to the rainfall throughout the Dominion. By reference to this, it may be seen at a glance what the average rainfall is in any of the fruit-growing localities (indicated by numerals).

In the table of meteorological observations for 5 years, 1918-1922, compiled from Meteorological Reports *(34)*, records as to rainfall, temperature, humidity and sunshine (where available) are

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* Numbers in italics refer to literature references cited in the bibliography on p. 349.

TABLE I.:

METEOROLOGICAL OBSERVATIONS FOR 5 YEARS, 1918-1922, INCLUSIVE.

Locality.	Temperature of air in shade, F.				Humidity. Saturation = 100.			Rainfall.		Sunshine.	Year.
	Mean.		Extreme.		Mean.	Max.	Min.	For year in inches.	No. of days on which rain fell.	In hours.	
	Max.	Min.	Max.	Min.							
Auckland	64.6	53.0	78.0	35.0	80	84	72	54.36	229	1,957	1918.
Tauranga	64.9	45.8	84.5	24.5	—	—	—	57.01	175	—	
Greenmeadows . *(Hawke's Bay)*	—	—	68.6	28.0	—	83	66	—	—	—	
Masterton .. *(Wairarapa)*	64.8	44.1	89.0	24.8	75	86	71	41.45	183	1,817	
Nelson	63.9	47.0	86.0	29.0	—	—	—	46.33	124	—	
Lincoln .. .. *(Canterbury)*	62.1	42.1	91.0	25.0	75	84	64	24.21	133	2,106	
Dunedin	57.8	44.1	81.0	28.0	65.6	79	59	36.9	159	—	
Auckland	63.8	50.8	81.0	38.5	82.2	89	76	33.55	174	2,003	1919.
Tauranga	65.7	45.0	86.0	28.5	—	—	—	36.39	115	—	
Greenmeadows .	65.6	47.2	88.0	29.5	70.7	79	62	22.6	58	2,659	
Masterton ..	65.9	42	87.6	22.4	71.8	79	65	28.3	145	2,276	
Nelson	63.6	—	83.5	22.0	—	—	—	20.58	96	—	
Lincoln	63.2	41.6	88.8	21.8	71.2	85	60	23.34	110	2,425	
Dunedin	58.3	43	84	29	64.2	71	60	42.9	175	—	

Auckland	63.9	52.7	77.5	36.0	74	80	60	58.17	164	1,922	1920.
Tauranga	65.1	46.1	87	28.0	—	—	—	68.93	155	—	
Greenmeadows .	65.3	48.1	92.5	30.5	72	82	66	26.92	87	2,373	
Masterton . .	65.2	44	87.4	25.4	74	81	66	40.14	156	1,828	
Nelson	62.3	46.9	87	25.4	—	—	—	49.05	114	—	
Lincoln	62.8	41.7	88	24	76	84	63	28.36	123	2,152	
Dunedin	58.8	43.2	90	27	63	70	56	28.45	159	—	
Auckland	64.4	53.3	78.5	37.5	—	92	74	39.69	156	1,905	1921.
Tauranga	65.4	45.3	86	28	—	—	—	44.93	135	—	
Greenmeadows .	65.9	48.5	93	31.5	72	78	65	22.36	—	2,422	
Masterton . .	64.9	43.4	92.6	24.8	71	81	64	37.26	145	2,096	
Nelson	62.7	45.8	91.5	27.5	—	—	—	37.42	119	—	
Lincoln	62.8	43.1	100.2	25.1	74	84	62	21.31	113	—	
Dunedin	—	—	88	31	—	88	—	29.72	165	—	
Auckland	65.2	53.5	82	37.5	81.2	89	77	48.06	198	2,111	1922.
Tauranga	66.1	46.9	83	29	—	—	—	45.69	151	—	
Greenmeadows .	—	—	87	28	—	84	66	—	174	—	
Masterton . .	64.3	43.9	89.4	23.2	74	83	64	27.38	—	1,982	
Nelson	63.4	46	79.9	29.4	—	—	—	35.71	122	2,602	
Lincoln	—	—	91	22.5	—	82	61	17.07	96	—	
Dunedin	58.2	44.4	83	29	73.7	88	59	38.09	177	1,496	

given. The localities chosen are in or near the centre of fruit-growing districts. These records, unfortunately, are in some localities incomplete. Figures for the Central Otago region are not given for they vary so much according to district; figures for this locality are given on p. 55.

FRUIT-GROWING AREAS OF THE DOMINION.

The following table, compiled from the Statistical Report *(19)*, gives the areas under orchard for the various fruit-growing districts of New Zealand:—

TABLE II.:

AREAS IN ORCHARDS (IN ACRES), 1922-1923.

District.	Commercial Orchards.		Non-commercial Orchards.
	Bearing.	Non-bearing.	
North Auckland ..	3,791	1,313	1,348
Auckland	512	78	815
Tauranga	135	61	193
Gisborne	160	26	166
Hawke's Bay	1,627	638	243
Taranaki	36	1	127
Wairarapa	161	6	122
Wellington	239	20	565
Nelson	7,679	1,646	341
Marlborough	570	79	144
Westland	25	2	29
Canterbury	1,495	524	909
Otago	365	79	207
Central Otago	3,429	454	250
Southland	11	2	220
Total	20,235	4,929	5,679

GRAND TOTAL, 30,843 ACRES.

These figures do not altogether agree with those obtained by the Horticulture Division, Department of Agriculture, for the total acreage in commercial orchards, compiled from their lists of registered orchards, is 28,960 acres. It is probable that under the heading non-commercial orchards in the Statistical Report, are included many small commercial areas.

Figures for the previous four seasons show that there has been a gradual increase in the number of acres coming into bearing:

	1918-19.	1919-20.	1920-21.	1921-22.
Orchards in bearing	14,182	15,545	16,603	17,607
Non-bearing ..	12,968	10,959	9,235	7,604

Prior to this period the figures given have been based on estimates, and are in consequence not reliable, and so are not given here.

Table III., on page 6, compiled from supplements to the *New Zealand Gazette (9), (10), (13),* and Statistical Reports *(17), (19),* covers a period of five years, and gives the number of bearing trees (trees that have been planted for more than six years) of each variety of fruit, the yield of each in bushels, and the average price realised per bushel.

As the industry has developed, it has been necessary to find markets overseas, leading to a gradual development of the export trade. This development received a check during the war period, owing to the shortage of shipping; consequently during the years 1917, 1918 and 1919 no fruit was exported.

The figures available since 1908 to 1924 are given in the following table:—

TABLE IV.:
SHOWING EXPORT OF FRUIT, IN BUSHELS.

Year.	Bushels.	Year.	Bushels.
1908	1,236	1917	Nil
1909	191	1918	Nil
1910	5,647	1919	Nil
1911	6,031	1920	33,576
1912	14,869	1921	48,912
1913	33,000	1922	112,345
1914	67,964	1923	147,659
1915	62,164	1924	243,429
1916	19,246		

TABLE III.: YIELDS IN BUSHELS, AND AVERAGE PRICES PER BUSHEL FOR SEASONS 1918-19—1922-23, INCLUSIVE.

Variety.	Number of Trees.	Yield in Bushels.	Average Price per Bushel.	
Apples	1,200,532	698,043	5/3	Season 1918-19.
Pears	124,414	112,936	6/3	
Quinces	2,270	1,911	5/2	
Peaches	186,267	119,421	6/11	
Nectarines	25,943	15,961	7/9	
Apricots	74,229	52,569	9/4	
Plums	74,435	73,923	5/–	
Cherries	16,158	5,467	30/9	
Oranges	1,886	2,989	9/4	
Lemons	7,003	5,798	11/11	
Apples	1,304,671	1,123,858	5/5	Season 1919-20.
Pears	126,130	182,301	5/6	
Quinces	2,302	2,285	4/7	
Peaches	169,803	131,728	7/6	
Nectarines	23,065	15,099	7/6	
Apricots	78,349	56,644	8/10	
Plums	69,646	66,362	5/10	
Cherries	18,280	7,244	31/4	
Oranges	1,852	2,534	10/3	
Lemons	8,032	41,884	12/9	
Apples	1,444,873	988,968	6/8	Season 1920-21.
Pears	142,189	167,623	6/8	
Quinces	1,992	1,838	5/7	
Peaches	151,296	91,050	10/9	
Nectarines	19,560	11,628	10/1	
Apricots	81,617	57,461	9/6	
Plums	70,143	68,364	6/–	
Cherries	21,495	7,827	31/2	
Oranges	2,974	2,339	11/2	
Lemons	10,568	7,500	10/9	
Apples	1,604,271	989,614	6/3	Season 1921-22.
Pears	142,503	157,261	6/3	
Quinces	2,289	2,041	5/2	
Peaches	143,823	115,415	9/3	
Nectarines	18,577	13,630	9/6	
Apricots	79,006	75,728	8/10	
Plums	67,349	67.189	6/7	
Cherries	20,291	5,538	33/11	
Oranges	2,572	3,439	8/10	
Lemons	13,661	10,965	9/11	
Apples	1,905,992	1,469,242	5/–	Season 1922-23.
Pears	145,317	189,848	4/8	
Quinces	2,546	2,233	5/2	
Peaches	137,672	132,201	6/9	
Nectarines	19,693	15,028	7/1	
Apricots	80,002	81,539	6/7	
Plums	64,540	65,553	5/6	
Cherries	21,810	7,421	28/10	
Oranges	2,417	3,738	6/4	
Lemons	16,223	10,998	9/1	

CHAPTER II.

ELEMENTAL BOTANY OF THE FRUIT-TREE.

The Cell; Root; Branch; Leaf; Photosynthesis; Transportation of Water and Soil Solutes; Transportation of Foods; Excretion; Respiration; The Flower; Leaf and Blossom Buds.

A knowledge of the structure and functions of a fruit-tree is essential to an understanding of the problems of plant diseases, otherwise the comprehension of such diseases as apple-scald or bitter-pit would be impossible, for throughout this book the subject matter has been written with the assumption that the reader possesses a knowledge of the anatomy and physiology of a flowering-plant. For those lacking this knowledge, the following chapter is written. It has been made as elemental as possible, all unnecessary terms or discussions being avoided.

Each part of a tree, whether branch, leaf or fruit, is composed of numerous tissues, each of which, in turn, is made up of numbers of cells. Therefore a discussion on the cell is necessary before the structure and function of the tissues as a whole can be understood.

THE CELL.

If a thin section of the fruit of an apple is placed under the microscope, it will be seen to consist of numerous, colourless, rounded cells, each containing semi-fluid contents. Further examination reveals the presence of other structures, of which the following will be discussed here:—

1. The cell wall.
2. The ectoplasm. } The protoplast.
3. The cytoplasm. }
4. The nucleus. }
5. The plastids. }

1. THE CELL WALL.

This consists of cellulose, and is manufactured by the protoplast. It serves to protect the enclosed protoplast, and, when forming part of a tissue, to give rigidity to that tissue as a whole.

2. THE ECTOPLASM.

This is a very thin membrane, enclosing the whole of the cell contents. It generally lies in close contact with the interior of the cell wall. It is one of the most important structures of the cell, for it governs the exchange of materials passing into and out of the cell. It also secretes the cell wall.

3. THE CYTOPLASM.

This is the living matrix in which the nucleus and plastids are embedded. It may occupy the greater part of the cell, or, in old cells, form a thin film around the cell wall. It is seen to be traversed by numerous cavities, or vacuoles, which may be filled with cell-sap, or with starch or other substances. Each of these vacuoles is in turn lined with ectoplasm, which governs the inward and outward passage of materials. The cytoplasm probably serves to carry out certain functions, such as the elaboration of reserve food, and the secretion of ferments, by means of which these reserve foods are re-converted into available foods when required.

4. THE NUCLEUS.

This structure is present in every living cell, and arises always by the division of a previously existing nucleus. Its function is imperfectly understood, but that it plays some significant part in the life-processes of each cell is made evident by the fact that if the nucleus is removed, the remainder of the cell-contents die. Nuclei are primarily concerned in the transmission of hereditary characters of the parents. Further, they serve to initiate and control the process of cell division, a matter that need not be discussed here.

5. THE PLASTIDS.

These are variously shaped bodies embedded in the cytoplasm. According to their colour they are named:—

leucoplasts	. .	colourless.
chromoplasts	. .	yellow or red.
chloroplasts	. .	green.

The *leucoplasts* take carbohydrates out of solution in the cell-sap, and store these within themselves as starch grains. They may also change to chromoplasts or chloroplasts. The *chromoplasts* give to flowers and fruits their red, yellow or orange colour. The *chloroplasts* secrete the green substance chlorophyll, which is employed by them in utilising energy from the sun, by which food substances are elaborated for use. This matter is more fully discussed under "leaf."

All these structures may be found in certain lowly one-celled plants, showing that a single cell, under certain conditions, is capable of living an independent existence. This condition does not exist in the higher plants, for with them, by the process of evolution, has arisen a highly complex structure, the cells of which are aggregated into tissues, each of which performs certain functions. Thus by specialisation of groups of cells to perform certain functions has arisen the complex structure which to-day we term a fruit-tree.

As will be seen, certain groups of these cells are modified to form a rigid skeleton, capable of bearing the heavy weight of branches and leaves; others are modified to form organs of reproduction; others again to elaborate the food substances necessary for the countless numbers of living cells throughout the tree, and so on.

It will be seen, however, that the activities of any tissue are dependent upon the protoplasm contained within each individual cell, the activities of each of which in turn appear to be controlled by the nucleus. All the protoplasts are in communication one with another by means of delicate protoplasmic processes, which pass from cell to cell, so that one can imagine a large tree to consist of a mass of semi-fluid protoplasm, made rigid by the close association of the walls of countless cells, secreted by the protoplasts themselves.

To attain to this degree of development has been a long process, during which the tree has been built up, cell by cell, year after year. All the substances necessary to build such a structure have come from the soil and from the air, been taken into the plant, and there elaborated to form the cell-walls of cellulose (which in mass we term wood) and that complex substance, the essentials of which we know nothing, yet which is the controlling force which builds the structure, the protoplasm.

In a primitive plant such as a one-celled alga, the cell after a time divides, so that two individuals essentially alike are produced. This is a simple form of reproduction, and can occur only when the cell has increased in size. Similarly with higher plants, the cells during the growth period enlarge and divide, then occupying about twice the space formerly occupied. In this manner a plant grows.

With higher plants growth is confined to certain regions, notably the tip of the shoot and root. Here cell division is an active process (during the growing season), and numerous cells are constantly being formed. These shortly become differentiated into groups of cells, or tissues, and become modified in structure to perform their allotted function. It is not necessary to follow in detail these changes, but it should be remembered that all these tissues about to be described, functioning as mechanical supports, water conduction vessels, etc., have arisen from undifferentiated cells formed at the growing apex.

We may now pass on to a consideration of these tissues. For convenience of discussion, a fruit-tree may be divided into the following parts:—

a. Root.	*d.* Flower.
b. Branch.	*e.* Fruit.
c. Leaf.	*f.* Buds (leaf and blossom buds).

a. ROOT.

The roots may be said to perform two functions:

1. To anchor the tree to the soil, and prevent it from being blown over by wind, and to give a firm base for the branches; and
2. To absorb and carry to the branches, water with food substances in solution.

The first function need not be considered further, for the second is the one which principally concerns us. The main roots give off secondary roots, these tertiary, and so on until near the tips the roots are exceedingly fine. Radiating out laterally from these finer roots are very numerous colourless cells, or *root-hairs* (Fig. 2). These hairs are exceedingly delicate, and are able to penetrate between the soil particles. It may be mentioned that, in the average soil, around each small particle is a fine film of water. This holds in solution various substances that are necessary to plant growth. The fine root-hairs come in contact with and absorb a portion of this soil moisture, which, together with certain of the substances in solution, is taken into the plant. If these delicate hairs were from some cause destroyed, no further intake could occur until fresh ones had grown out from the root.

This water, with its contained food material, must pass through the cell wall, the ectoplasm lining the inner wall of the root-hair, and the cytoplasm, before it can pass to the vessels by which it is taken to the leaf. The processes by which this water enters the root-hairs are termed osmosis and diffusion. These processes are as yet imperfectly understood, but may be partially explained as follows:—Certain sugars or acids present in the vacuoles of the cytoplasm within the root-hairs attract water, provided the concentration of the solution within the cell is greater than that of the solution in the soil; consequently the soil solution passes to the cell, and there is passed to other cells in turn, the strength of the cell

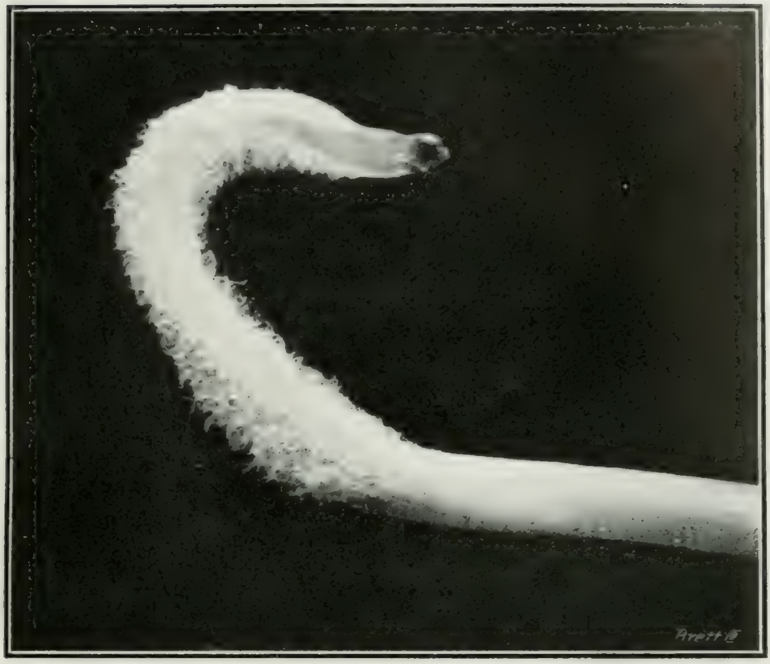

Fig. 2. ROOT-TIP OF PEA, SHOWING NUMEROUS ROOT-HAIRS. × 10.
Photo. H. Drake.

solution thus remaining constant. This absorption occurs only when the soil solution is such that it would be favourable to plant growth; were it toxic, then the ectoplasm would exert a selective influence and become impermeable. Were the concentration of the solution in the soil to be greater than that of the cell, the ectoplasm may still exercise this selective influence, becoming impermeable, so that the solution in the cell would not be lost. Further, were the protoplast in the cell to be killed, the solution would then diffuse out, for the ectoplasm, being dead, would not act as a barrier; this would prevent the passage of harmful substances to the root, for in the absence of a solution in the dead cell no intake of soil solutes would be possible.

The root-hairs also secrete certain acids and carbon dioxide. These go into solution in the soil water, and there may dissolve certain substances in the soil, rendering them available for use by the plant.

Once in the root, the soil solutes pass to tissues specialised for the rapid upward transport of water. These tissues consist for the most part of tracheal tubes, and pass from the root, through the stem and branches, to the leaf. The structure of the root differs somewhat from that of the stem, but these differences need not be discussed here, for they are of minor importance.

b. THE BRANCH.

(Stem and laterals are essentially alike.)

The two main functions of a branch are:—

1. To serve as a support for the leaves and fruit.
2. To serve as a channel through which water containing soil solutes may pass to the leaves, and food substances pass from the leaves to the roots.

The branch consists of numerous groups of tissues, each modified to perform certain functions; of these, only the following need be discussed here:—

1. Bark	Epidermis. Phellogen.
2. Cortex ..	Cortex. Phellogen. Phloem.
3. Cambium ..	Cambium.
4. Wood	Xylem. Medullary rays.
5. Pith	Medulla.

1. BARK.

Although this term is frequently used for all tissues lying upon the wood of a branch, it here is limited to that layer of hard, brown tissues forming a covering over the underlying soft tissues. In old trees it may be 12mm. or more in thickness, but on one-year-old laterals may be altogether absent. This covering on young laterals is the *epidermis,* consisting of a tissue of minute cells differentiated at the growing point of the shoot. On very young shoots the epidermis may appear green, owing to the presence of chloroplasts in the cells beneath. As it becomes older, the epidermis becomes thickened and hardened, the walls of the cells become infiltrated with a waxy substance named *cutin,* and this same substance is deposited as a thin film (the *cuticle*) over the surface of the epidermis. The object of this infiltration and of the formation of the cuticle is to make the cells impervious to the passage of water. It serves also as some protection against insects and fungi.

Later, towards the end of the first year, beneath the epidermis is formed a layer of cells—the phellogen or *cork cambium* the chief function of which is to provide several layers of cork cells. These cells act as an insulating layer, cutting off food supplies from the epidermis, which dies and falls away, and preventing the outward or inward passage of water or gases. But, as will be seen later, air is necessary to every living cell, and if this cork layer were continuous over the whole tree, air would be excluded, and the cells beneath would die; so that at frequent intervals minute lenticels are to be seen penetrating the bark (Fig. 4).

The majority of living cells are not in contact with one another at all points, for frequently, where two or three abut, are to be seen spaces which are termed intercellular spaces (see under the discussion on the leaf). These are filled with air or gases, and really form air passages throughout the living tissues, which permit of the passage of air to, and carbon dioxide from, the protoplasts within the cells, the exit to the exterior being by way of the lenticels. Production of cork tissue, or bark, goes on constantly during the life of the plant, so that on old trees this layer may be seen to be quite thick.

2. CORTEX.

Between the bark and the cambium (the layer lying next the wood) lies the cortex, consisting of numerous groups of soft tissues. Of these tissues, it may be said that some are modified to give rigidity to the shoot ere the wood is developed, and to a certain extent (when chloroplasts are present in the cells) to elaborate food substances. These activities soon cease, and, in a branch of more than a year old, only one group of tissues is of sufficient importance to be discussed here. This, the *phloem,* is the tissue by which practically the whole of the elaborated food substances of the plant are conveyed from the leaves to growing parts, or to places where they are temporarily or permanently to be stored. The phloem consists of three groups of cells, through two of which, the *sieve-tubes* and *phloem parenchyma,* the proteids and carbohydrates (available foods for the protoplasts) pass to wherever they may be required. The phloem is in general functional for only one season; it is in communication with the leaves and roots, as well as other tissues of the cortex. It is derived from the cambium.

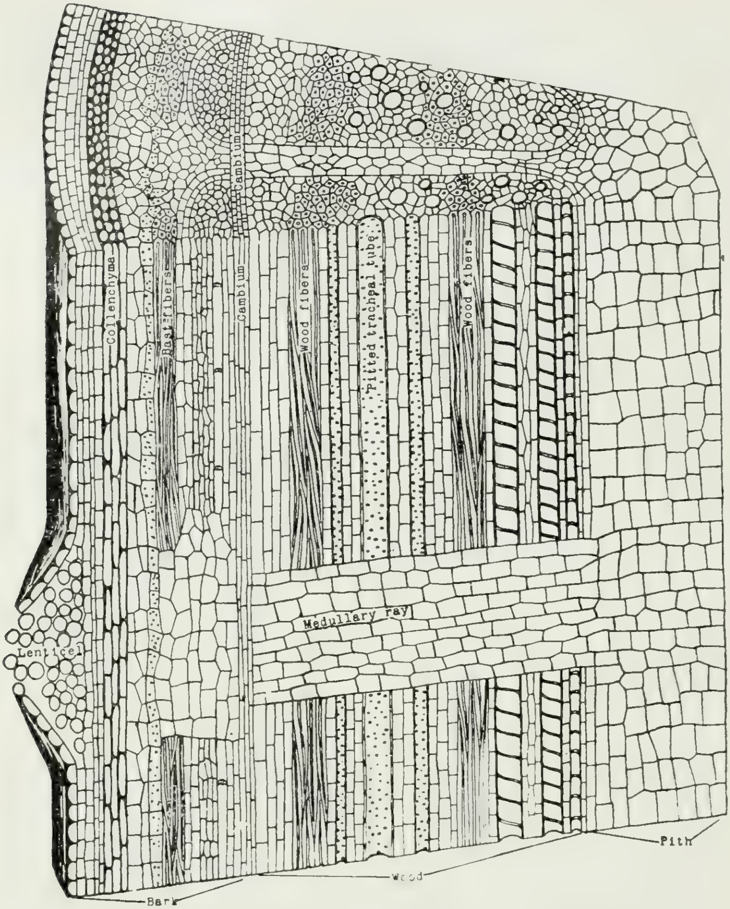

Fig. 3. SECTION OF STEM; DIAGRAMMATIC DRAWING SHOWING STRUCTURE OF BARK, WOOD, AND PITH. Magnified.

Reproduced from Stevens (295).

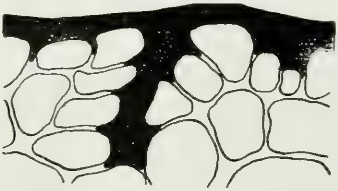

Fig. 4. SECTION THROUGH EPIDERMIS OF MATURE QUINCE FRUIT SHOWING LENTICEL PLUGGED WITH WAX (in black). × 300.

Original.

3. THE CAMBIUM.

Lying between the cortex and the wood is a very thin tissue, 3-4 cells deep, the *cambium* (Fig. 3). It is one of the few tissues of the plant the cells of which have retained the power of growth by division. From it are produced all the cells of the wood and the phloem, and during the growing season it is producing constantly the various cells of which these tissues are composed. A remarkable property possessed by the cambium is that it can produce a cell which, if cut off on the outer side, develops into a phloem element, and if cut off on the inner or wood side, develops into a xylem element.

The importance of the cambium will be made more evident in the section dealing with wounds (p. 32). For should a portion of the bark and cortex be removed, so as to expose the wood, it will be found that no further growth will occur in this region until the wound has callused over. This callus tissue is produced from the cambium.

4. THE WOOD.

That portion of a branch or stem lying beneath the bark and cortex is termed the wood. It is seen to be hard and rigid, and in fact forms the mechanical support of the tree.

The wood consists of two groups of tissues, the *xylem* and the *medullary rays* (Fig. 3). The xylem consists of numerous cells, modified to perform special functions. The chief of these cells are the *tracheal tubes*, through which the water and soil solutes pass to the leaves. Associated with these are other cells, which have greatly thickened cell-walls, and serve chiefly to give the necessary rigidity to the wood. In the spring months, when the water requirement of the tree is greatest, the tracheal tubes predominate, consequently wood formed in the spring is less solid (because of the greater number of these vessels) than wood formed in the autumn, in which the tubes have a much smaller diameter. As the tree grows, year after year are thus formed rings of wood, which appear visible to the eye as the "annual rings."

As a rule, the chief water-carrying vessels are present in the current season's growth, but certain of the older vessels are capable of functioning in a similar manner. In the wood of an old tree, however, the whole of the central portion, or heart-wood, consists of dead cells, and does not so function; in fact, one may picture an old tree as consisting of an external cylinder of living tissues enclosing a column of dead tissues.

The *medullary rays* are narrow bands of cells running radially from the wood to the cortex. They are in intimate relation with both phloem and xylem elements. They serve as passages through which elaborated foods may be carried to and stored in the cells

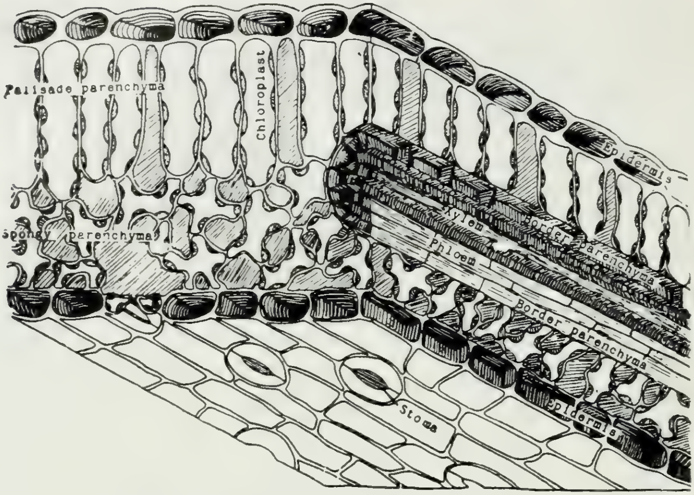

Fig. 5. DIAGRAMMATIC DRAWING OF SECTION OF A LEAF SHOWING STRUCTURE. Magnified.

Reproduced from Stevens (295).

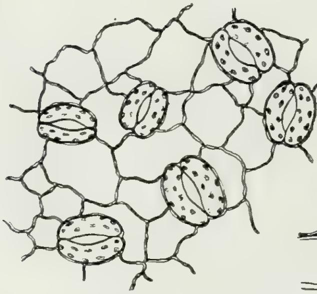

Fig. 6.

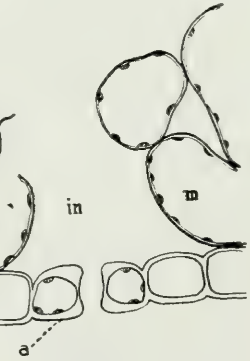

Fig. 7.

Fig. 6. STOMATA OF APPLE LEAF. × 250.
Outline drawing showing their prevalence.

Fig. 7. STOMA OF APPLE LEAF. × 650.
Section through stoma. *a.* Guard cell; *m.* mesophyll cell; *in.* intercellular space.

Original.

of the wood; and through which these foods may be carried to the phloem elements when required. They serve also to carry water and soil solutes to the cortex; and, in short, serve as passages through which foods may pass to wherever they are required by the living cells.

c. THE LEAF (Fig. 5).

The leaf is that organ of the plant in which the soil-solutes taken in by the root, together with certain gases from the air, are elaborated, by energy derived from certain of the sun's rays, into substances which may be utilised by the living cells as food.

The functions of the leaf will be better understood when its structure is known. The leaf consists of a stalk or *petiole,* by which it is attached to the shoot. The petiole is flexible, so that the leaf may move freely in the wind. Attached to the petiole is the blade or *lamina,* which is thin and flattened, and on the tree will usually be found in a position in which its surface is at right angles to the sun's rays. Traversing the lamina are the mid-rib and numerous "veins." These serve to give strength to the leaf, and also to distribute to all portions of the lamina the water and contained solutes taken from the soil, and to convey from them the food substances elaborated in the cells of the leaf.

A transverse section through the lamina shows it to consist of the following structures:—

1. Epidermis.
2. Mesophyll
   - Palisade parenchyma.
   - Spongy parenchyma.
3. Vascular bundles (or veins).

1. THE EPIDERMIS.

The epidermis is present on both surfaces of the leaf. Its function is essentially one of protection, for the cells of which it consists are infiltrated with cutin, and the upper surface especially usually has an overlying cuticle. This protective covering is to prevent the egress of water, for, as will be seen, a special mechanism is developed to control the passage of water from the leaf. The prevention of undue loss of water is carried further by the provision of hairs or other structures on the leaf. The epidermis is transparent and allows light rays to penetrate to the mesophyll cells.

In one or both surfaces, usually the lower, are numerous minute openings, or *stomata* (Figs. 6, 7). These are very small and numerous, for from 100 to 2,000 per square millimetre may be present. In structure they are seen to consist of two large cells, the guard cells. These cells have the property of being able to move towards or away from one another. When they move towards one another they close the opening and thus prevent the passage outwards of water vapour; when they open away from one another an elliptical opening is formed, and as this is in communication with spaces between the cells of the leaf, water vapour and gases may pass outwards, or air inwards. This movement is governed by the requirements of the cells of the leaf, for when the cells are turgid and the sun is shining, the stomata open; when flaccid, or during the hours of darkness, they close.

2. MESOPHYLL.

The mesophyll consists of the chlorophyll-containing cells. These are arrayed in two well-defined zones. The layer (or layers) beneath the epidermis consists of numerous cylindrical cells, whose long axes are at right angles to the epidermis, arrayed in palisade fashion, and termed the palisade parenchyma or palisade layer. Below these are numerous irregular cells, more loosely arranged, with large intercellular spaces between, forming the spongy parenchyma. Intercellular spaces also occur between the cells of the palisade layer, and, in fact, every cell in the leaf has one or more of its surfaces in contact with an interspace.

In the mesophyll cells are numerous chloroplasts, each containing the green substance chlorophyll. The chloroplasts are small bodies which are arranged in a definite manner, according to the light requirements of the plant. They are able to manufacture within themselves the chlorophyll. By the aid of energy derived from certain of the sun's rays the chloroplasts are enabled to elaborate the necessary food substances; this process, *photosynthesis,* is discussed more fully below.

3. VASCULAR BUNDLES (Fig. 5).

The bundles are in communication with the conducting vessels of the branch and stem, and through these with the root. They enter from the branch to the leaf by way of the petiole, and in the lamina branch repeatedly to form a complex network. Each bundle consists of both phloem and xylem elements; through the former the elaborated foods are carried from the leaf to the branch, there to be distributed to wherever they are required; through the latter, water with soil solutes passes from the roots into the leaf. Each of the smaller vascular bundles is surrounded by a layer of cells (border parenchyma), which is in intimate contact with the mesophyll cells. Through this layer the water (and soil solutes) passes to the mesophyll cells.

PHOTOSYNTHESIS.

In this complex process several factors play a part; three things necessary are:—

Carbon dioxide (CO_2).
Water (H_2O).
Light rays from the sun.

The carbon dioxide is present in the atmosphere to the extent of 3 parts in 10,000; it passes into the leaf through the stomata, and, together with water obtained principally from the xylem elements of the vascular bundles, passes into the mesophyll cells. Here, in some manner unknown, by the energy of certain of the sun's rays arrested by the chlorophyll, the water and carbon dioxide are synthesised into carbohydrates, such as sugar or starch, but the exact substance first formed is unknown. As a bye-product of this reaction oxygen is given off, part of which may be utilised by the cells of the leaf, but most of which passes through the stomata into the air.

If the starch thus formed were to remain in the leaf, photosynthesis would quickly be brought to a standstill, so that the plant has evolved a method of carrying this substance away from the leaf and storing it until required. This is dealt with under the section "Transportation of Foods." Carbohydrates contain only the three elements—

Carbon	C,
Hydrogen	H,
Oxygen	O;

and may exist in the form of starches, sugars, fats, or cellulose, the last being the substance of which the cell-walls are built. Chlorophyll, on the other hand, is a much more complex substance, and has the probable formula $C_{31}H_{29}N_4Mg_3\,(COOH)_3$. Protoplasm, again, is a complex substance, the chemistry of which is unknown; but it certainly contains nitrogen, sulphur and phosphorus.

In daylight and in the presence of carbohydrates these proteid substances, such as protoplasm and chlorophyll, are synthesised, principally in the leaves, the necessary nitrogenous and other substances being derived from the soil solutes brought to the leaf from the roots.

We have now dealt with the manner in which water and soil solutes enter the plant through the root, and described the channels by which it passes to the leaf, and the functions of the leaf, branch and root. It remains now to deal with the method whereby the water is lifted to the leaves, the manner in which the cells throughout the tree receive their necessary quantities of food substances and oxygen, how they get rid of waste products, the manner in which foods are stored in reserve and the reason for such storage.

TRANSPORT OF WATER AND SOIL SOLUTES.

Water transport is effected by certain of the xylem elements. These elements are so constituted that water may pass from one side of a branch to the other, thus minimising the detrimental effects that would otherwise follow through root injury. The actual forces governing the ascent of water are unknown, but it is probable that osmotic pressure exerted by the cells of the root tends to lift it some way, that capillary attraction within the tracheal tubes helps, and that the osmotic attraction exerted by the mesophyll cells of the leaf also assists. The amount of water given off from the leaves of a large tree is surprisingly large, for it has been found that certain forest trees may give off as much as 350 kg. (780 lbs.) in 24 hours; or, in the case of apple trees, 566 litres (124 gallons) during the first three months in leaf.

TRANSPORTATION OF FOODS.

The transportation of foods is dependent on certain of the phloem elements. The food substances, carbohydrates and proteids (for soil solutes cannot be utilised by the plant until they have been combined with carbohydrates to form proteids) pass from the mesophyll cells in which they have been synthesised, to the small vascular bundles ramifying in the leaf; here they are taken up by the phloem, which conducts them through the leaf petiole to the branch. Hence they may pass upwards or downwards to wherever food is required by living cells, and may be transported laterally in the medullary rays to the wood cells. Transportation of these substances is possible only when they are in solution. Foods are produced in greater quantity than is required by the plant, and this excess is in part carried to the developing fruits or seeds, and the remainder stored until such time as it is required, in the cells of the medullary rays and wood.

Storage of foods is necessary to the plant, for during the dormant season food manufacture cannot occur, owing to the absence of leaves, and all the living cells, although dormant, still require a certain amount during this period. Further, reserve foods are needed to enable leaves and blossoms to develop in the spring.

Foods are stored in the form of—

1. Carbohydrates.
    - Cellulose.
    - Fats.
    - Oils.
    - Starch.
    - Sugars.
2. Glucosides.
3. Proteids.

When required, the insoluble compounds, such as starch, oil and proteids, are rendered soluble by the action of particular secretions of the protoplast, called *enzymes*. They then pass into the phloem elements and are carried wherever they may be needed.

EXCRETION.

Waste products, if soluble, may pass from the plant, or may be deposited in the form of crystals in leaves shortly before leaf-fall. In other cases, certain vacuoles in cells are found to contain numerous crystals, or certain cells may be found filled with tannin. It is probable that in this manner plants get rid of those substances for which they have no further use.

RESPIRATION.

One other element essential to the living cell is oxygen, for the protoplasts of a plant take in oxygen and give off carbon dioxide, just as do the protoplasts of the animal body. Consequently it is necessary that all living cells obtain quantities of this gas. Reference has been made to the intercellular spaces found in various tissues. Through these air passes, and from this air the requisite quantity of oxygen is taken by the protoplast of the cell. In return, carbon dioxide is given off, and passes through the intercellular spaces to the lenticels (in the stem) or the stomata (in the leaf), and thence to the exterior. These intercellular spaces penetrate between the living tissues, and pass even to the extremities of the roots. Thus there is a constant inward passage of oxygen and an outward passage of carbon dioxide during the whole life-time of a plant.

d. THE FLOWER.

The flower is composed of the structures which give rise to the sexual organs of the plant. To attract insects, and thus ensure pollination, it usually is brightly coloured. In nature it is chiefly by means of the seeds produced by a plant that it is reproduced, consequently it is not surprising to find the flower and its associated structures in a high and complex state of development. In fact, one may go further and state that the ultimate object of every plant is to reproduce itself, and that the complex leaf, stem and root are subservient to this end. For the flower is developed as the highest form of specialisation of function; it takes no part whatsoever in the nutrition of the plant, its sole function being that of reproduction.

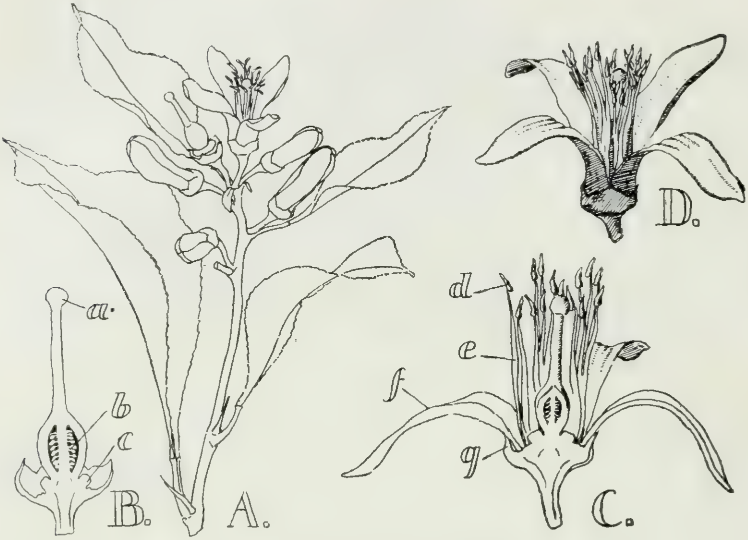

Fig. 8. LEMON SPRAY AND FLOWERS. Enlarged.
A. Spray; B. Section showing *a* stigma; *b* ovules; *c* receptacle; C. Section showing *d* anthers; *e* filament; *f* petal; *g* sepal.

Drawing by E. H. Atkinson.

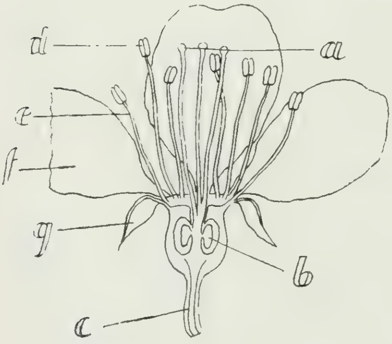

Fig. 9.

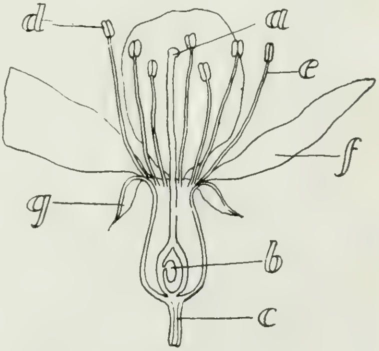

Fig. 10.

Fig. 9. SECTION THROUGH FLOWER OF APPLE. Natural size.
a Stigma; *b* carpel; *c* pedicel; *d* anther; *e* filament; *f* petal; *g* sepal.

Fig. 10. SECTION THROUGH FLOWER OF PEACH. Natural size.
Lettering as above.

Drawings by E. H. Atkinson.

The cultivated apple, peach or lemon of to-day is the outcome of selection by man over a long period, and the large and fleshy apple or peach is the product of this selection, the progenitors of these plants producing fruits about the size of a walnut.

1. THE APPLE FLOWER (Fig. 9).

An open flower is seen to consist of—

Pedicel.
Calyx-tube and sepals.
Corolla (petals).
Stamens.
Pistil.

The *pedicel* is that portion which attaches the flower to the branch. The *calyx-tube* is a green, fleshy structure, attached at the base to the pedicel and apically crowned with 5 sepals, small green structures which persist and form a false covering at the "blossom" end of the mature fruit. Inserted in the upper part of the calyx are the 5 coloured or white petals, which after fertilisation fall away; interiorly to these are the numerous stamens, each of which bears on its tip a small 2-lobed sac, the *anther*, containing very numerous pollen grains. Within the ring of stamens are the five *styles*, each crowned with a slightly viscid *stigma;* the styles continue downwards to the centre of the calyx-tube, which, when sectioned, is seen to contain five chambers, each containing two minute white *ovules*. The flowers usually are proterogynous—that is, the pistil (or female part) is in a condition suitable for pollination before the anthers (male part) are mature. When such is the case, self-pollination cannot occur. (In certain varieties, however, self-pollination is not uncommon).

Pollination is effected by bees and other insects. While searching in the flower for nectar, they become dusted with pollen, and when they visit other flowers in which the stigmas are receptive, certain of these pollen grains become attached to the stigmas. Here they germinate and produce pollen-tubes which grow down the stigmas to the ovules, where fertilisation is effected by the union of certain portions of the contents of the pollen-tube and the ovule. Fertilisation gives the stimulus necessary to the continued development of the fruit, which grows until it reaches maturity.

Should fertilisation not occur, the immature fruit after a time falls away, a phenomenon common on certain trees, notably pears. Hence the need for having in the orchard trees of different varieties (different individuals suffice with most varieties of apples) to ensure pollination.

2. THE PEACH FLOWER (Fig. 10).

This is similar to the preceding, save that there is a single chamber or carpel, containing two ovules. After fertilisation, the whole of the flower, save the ovary, falls away.

3. THE LEMON FLOWER (Fig. 8).

The flower is usually white, waxy and fragrant. There are 4-5 large white petals, 4-5 minute sepals, and the stamens are at their bases united into groups of an irregular number, but are free at their apices. Within the ring of stamens is the ovary, containing numerous carpels, each with several ovules. The style is compound, several being united together, and is covered with a large disc-like stigma.

e. THE FRUIT.

APPLE (Fig. 11).

The whole of what we term an apple is known as a *pome.* It consists of a fleshy portion, enclosing the "core," which develops from the five carpels or chambers mentioned under the discussion on the flower. In each carpel are two brown, tear-shaped seeds or "pips." The carpels are seen to be spaces within the fruit bounded by tough, smooth, cartilaginous structures. In some varieties it will be noticed that the chambers of the carpels are in communication with the exterior by a narrow passage, which may be termed the *calycine sinus* (Fig. 11). Fruits possessing this opening are susceptible to mouldy-core.

The "flesh" of the apple surrounds the five carpels or ovary, and although it is not known with certainty in what manner the flesh has arisen, it is believed to be the enlarged and succulent top of the flower-stalk or receptacle, investing the ovary. The flesh consists of very numerous, large pulp cells, crowded together and traversed by vascular bundles. Intercellular spaces are present throughout, lying in the angles formed where two or more of the cells abut.

VASCULAR BUNDLES.

These enter the fruit from the pedicel, and then divide into ten main branches, which run to the calyx end. From them, numerous strands are given off to the carpels, but the greater number of strands penetrates the flesh, and immediately beneath the epidermis produces an intricately branched network, forming

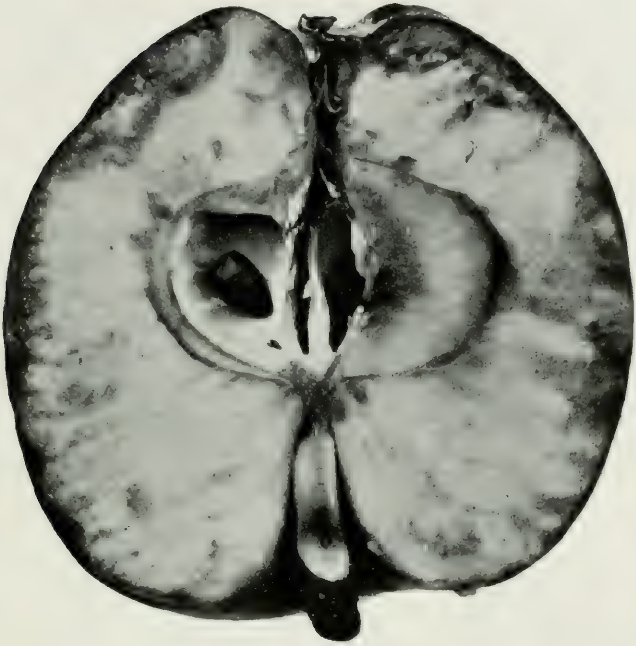

Fig. 11. SECTION THROUGH APPLE FRUIT SHOWING STRUCTURE.
Natural size.

This illustration shows the open calycine sinus through which spores may penetrate and produce mouldy-core.

Photo, H. Drake.

an almost continuous layer, a fact first pointed out by McAlpine *(215)*, from whose publication Fig. 91 is taken. This complex network serves both as a supporting structure and to supply food material to the pulp cells, and to the actively dividing layer immediately beneath the epidermal cells.

SKIN.

This consists of two layers—

a. Epidermis.
b. Hypodermis.

The epidermis is a transparent, cellular layer, overlayed with a waxy covering, the cuticle. The hypodermis consists of several layers of cells containing chloroplasts, which give to unripe fruit their green colour. When the fruit matures, the colour changes to yellow or red, due to the formation of certain pigments in the cell-sap, and probably to the presence of chromoplasts.

Stomata are numerous in developing fruits, but on approaching maturity most of these become plugged with wax, thus reducing the amount of transpiration. Small lenticels may also be found in the position formerly occupied by the stomata, and function as cavities through which gases may pass out or in, for respiration continues throughout the life of the fruit. Apples placed in cool-store respire much more slowly, and therefore keep for a greater length of time. Growth in the apple fruit occurs principally in a few layers of cells beneath the hypodermis, which tend to divide in a manner similar to cambial cells. In this book these layers of cells are termed the "cambium."

In the developing fruit, starch is present in quantity in the pulp cells, and when the fruit ripens this starch is converted into sugar.

The chemical composition of the ripe apple is as follows *(67)*:

	Percentage.
Water	84.0
Ash	0.3
Invert sugar (dextrose and levulose)	8.0
Cane sugar	4.0
Crude fibre	1.8
Pectin matter	0.4
Malic acid, free and combined	0.8
Oil or fat	0.3
Protein	0.1
Undetermined	0.3
	100.0

PEACH.

The single carpel of the peach develops into a *drupe*. The wall increases in thickness, and in the mature fruit consists of the three layers:—

a. Endocarp (stone).
b. Mesocarp (flesh).
c. Epicarp (skin).

The *endocarp* or stone consists of numerous, specially hardened cells closely compacted together, enclosing a cavity in which is present the two ovules or seeds, only one of which usually develops to maturity.

The skin is covered with numerous outgrowths or hairs, which possibly in the primitive plant functioned as a protective covering.

LEMON.

The fruit of the lemon is known as a *berry*. It consists of the three tissues—

a. Endocarp.
b. Mesocarp (flesh).
c. Pericarp (rind).

The *pericarp* or rind is thick and coriaceous. It consists of numerous layers of cells, externally covered by the epidermis, the cells of which at maturity contain a yellow pigment. In the tissues of the pericarp are numerous oil glands, containing an essential oil, which gives to citrus fruits their characteristic odour.

The *mesocarp* is formed of very numerous, large, fusiform cells, which project into and completely fill the loculi of the ovary. These cells arise as multicellular hair-like outgrowths from the endocarp. Embedded in these pulp-cells are the seeds, from 2 to 5 being present in each locule (section) of the ovary.

In all the fruits mentioned above there are two main parts—the seed and the fleshy portion. To the plant the former is of more importance, to man the latter. Man has, by continuous selection and breeding through many centuries, enormously enhanced the value of the fleshy portion without regard to the seed, which, in some cases, has been suppressed altogether. Thus modern fruits are highly specialised artificial products, whose well-being depends on constant attention lest they pay the penalty inherent in over-specialisation.

f. LEAF AND BLOSSOM-BUDS.

LEAF-BUD (Fig. 12).

This may briefly be described as an incipient or arrested shoot. If we take, by way of illustration, the lateral of an apple tree, it will be noticed that the leaves are arrayed at intervals along the length of the shoot, but become more closely compacted together as the apex is approached. If it were possible to "telescope" this shoot, something resembling a bud would be produced. The growing apex of the shoot is protected by overlapping immature leaves, and as the shoot develops these leaves increase in size, and become more and more separated, owing to the growth of the intervening tissues or internodes. When growth ceases in the autumn, the immature leaves remain surrounding the growing apex, where they are folded one over the other, so as to give the maximum amount of protection; in addition, certain *bud-scales* are produced, which serve as a further

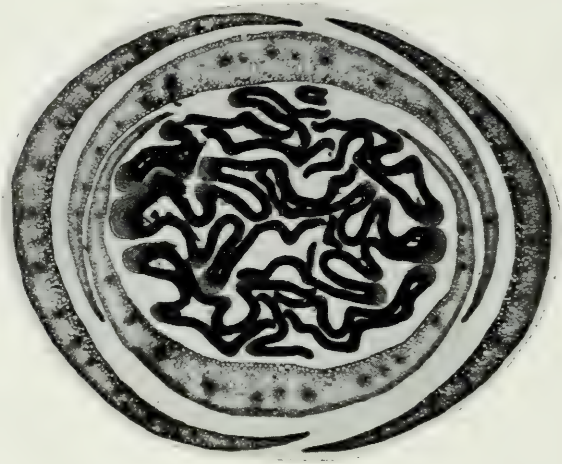

Fig. 12. TRANSVERSE SECTION THROUGH DORMANT BUD. × 10.
Bud-scales on the exterior, immature leaves in the centre.
Photo, H. Drake.

covering, protecting the delicate growing point and immature leaves against winter injury. Thus growth is merely arrested for the time being, and continues the following season. Buds may arise in the axils of the lateral leaves (between the base of the leaf and the shoot), and if unhindered will develop lateral shoots in turn.

BLOSSOM-BUDS.

These are essentially like leaf-buds, a blossom being in reality a simple shoot bearing the structures which give rise to the sex organs. Further, leaf-buds may give rise to blossom-buds, their prevalence being governed by the relative amounts of food substances present in the vicinity of the bud. For, if organic substances (substances elaborated by the plant) are in excess, blossom-buds result, whereas if water containing soil solutes is abundant, leaf-buds will be produced.

Blossom-buds are formed the summer previous to their flowering, so that the environmental conditions during the previous summer govern the number of blossoms which will appear the following season. It may also be stated that pruning would affect blossom production, for if trees were heavily pruned, a vigorous growth would ensue, with an accompanying upsetting of the balance of the ratio between organic substances and soil solutes. If a lateral were left unpruned, the proportion of organic substances in the tissues of that lateral would be much higher than soil solutes; if it were cut hard back, then the proportions would be reversed, with an increase in wood production. Thus by scientific pruning the grower should be able to produce wood or fruit at will, always remembering that the fruit crop of the *second* year would be the one that would be affected.

Flower buds may be—

a. Terminal.
b. Axillary.
c. Spur-borne (a spur is really a short and condensed shoot).

When large branches are removed from a tree, it is noticed that when growth commences in the spring, numerous shoots develop from the wood below the cut. No visible buds are present in this region. Similarly, if a two-year-old lateral is cut back to the main branch, it is noticed that from the vicinity of the cut young and vigorous growths appear. These are adventitious shoots. The theoretical explanation for this phenomenon is as follows:—Normal shoots arise as a result of the active division of certain tissue at the growing point, termed embryonic tissue. Adventitious shoots arise from certain embryonic cells in the cortex which have been "left behind," as it were, during the growth of the branch. These embryonic cells develop growing points, which in turn give rise to the shoot. The shoot is formed beneath the bark, and consequently must force its way through this to reach the surface. Certain of the cells of the older tissue are stated to be capable of returning to the embryonic condition, and producing new growing points, which in turn give rise to shoots.

For literature references regarding this subject, see bibliography, p. 349, numbers *52, 67, 152, 295.*

Fig. 13.

LARGE WOUND FORMED IN THE TRUNK OF AN APRICOT TREE AS THE RESULT OF A BRANCH BEING TORN AWAY.

This tree is infected with silver-leaf.

Photo by Author.

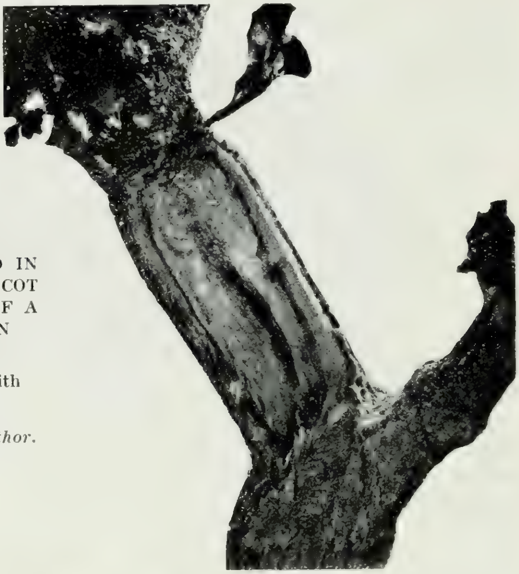

Fig. 13.

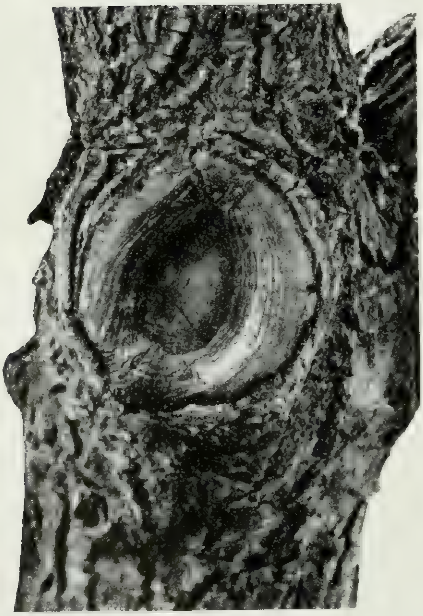

Fig. 14.

Fig. 14.

PARTIAL OCCLUSION BY CALLUS, A CONDITION FOLLOWING CAREFUL PRUNING.

Photo by Author.

CHAPTER III.

WOUNDS AND WOUND TREATMENT.

Wounds in Leaves; in Fruits; in Branches;
Wound Treatment; Treatment of
Cankers; Sterilising Agents.

WOUNDS.

Wounds penetrating through epidermis or bark to the underlying tissues are constantly being produced on plants, and unless treated in some manner are a source of danger, as through these injuries parasites may gain entry to the living tissues, and food substances may be lost through them. Consequently we find in plants efficient means of protecting these injured surfaces.

IN LEAVES.

Every time a leaf falls a wound is made, but the plant provides for this contingency by forming a protective covering over the region ere the leaf falls. The same applies to numerous trees which have the habit of shedding small laterals or branches.

An injury to the lamina of the leaf may be protected in the following manner. Gums or resins may flow out from certain cells and act as a temporary covering over the injured surface; but in general the exposed cells die and lose their contents, and themselves serve as a temporary protection. Beneath these dead cells, other cells, in response to the stimulus of the injury, produce rows of cork-cells, termed *wound-cork*. These rows of cork-cells act as an impermeable barrier to the passage of water or gases, and thus serve as an efficient protective covering. Their development is well seen in a leaf attacked by shot-hole. In such a leaf the fungus penetrates to the mesophyll, and there the hyphae ramify between and kill a group of cells, forming a small dead area, visible on the surface. In response to this wound stimulus, living cells in the vicinity begin to form wound-cork, with the result that the fungus is soon "shut off," as it were, from the healthy tissues by a circle of cork-cells, which prevents the further penetration of the hyphae. The dead cells then lose a certain amount of moisture and shrink slightly, with the result that separation occurs along the line of cork-cells, and the dead portion of the leaf, bearing the fungus, falls away, leaving a more or less circular perforation.

Production of this wound-cork would appear to be the principal means by which a plant protects any wounded surface of a leaf. Similar wound tissue is produced over injuries in the succulent tissues of herbaceous plants, tubers, roots and inflorescences.

IN FRUITS.

Similar production of cork-cells may occur in fruits. For example, if the epidermis of a developing apple is damaged, cork-cells are produced which act as an efficient covering, but tend greatly to affect the appearance and shape of the fruit. For if the epidermis is damaged whilst the fruit is small, the corky covering is developed, and this being hard and unyielding, is likely to become cracked as the fruit increases in diameter; along the margins of these crevices further wound-cork development occurs, and in this manner large and unsightly blemishes are formed, and the fruit is usually distorted. On fruits infected with black-spot, large corky areas may be formed, especially when infection has taken place on immature fruit (Fig. 40).

IN BRANCHES.

Where the injury penetrates just beneath the bark, further layers of bark may be produced over this region by the cork cambium. When the injury penetrates to the wood, a more complex series of reactions results. The wood may be coated with a thin film of gum, which would serve temporarily to protect it from pathogenic invasion; the tissues surrounding the wound die and become oxidised; and gum may be secreted in certain cells. Cork-cells are then developed over the whole of the exposed surfaces (excepting the exposed wood), and from the cells of the cambium and adjacent cells is produced an abundant tissue, which gradually grows over and covers the injured surface. This tissue is termed *callus* (Fig. 14), and the wound surface (when covered) is said to be *occluded*. A cork-cambium is formed in the callus, and bark produced, which covers it over as in the normal tissues.

When a branch is removed from the tree, the reactionary processes vary according to the age of the branch. If, for example, it is two or three years old, most of the cells of the wood and cortex will contain protoplasm, and in consequence respond to the wound stimulus. The exposed vessels die and become oxidised. They then become plugged with gums, which tend to prevent the penetration of casual water into, or food substances out of the vessels. Small cells, termed tyloses, also grow from adjoining cells into the vessels, plugging them completely. Many cells in addition become infiltrated with certain water-proofing substances, and it is probable that tannin is also produced in this connection. The cells of the cortex produce wound-cork, so that in a short space of time the wound is efficiently protected. Callus formation commences around the vicinity of the cambium, and in a season or more the wound is completely occluded.

If an old branch, many years of age, is cut off, the greater part of the exposed wood would consist of what may be termed dead cells, i.e., cells without living contents, for in old wood the thickened cell wall alone is present. Consequently wound stimulus is responded to only by the cells in the cortex, cambium and young wood. In these areas infiltration and plugging of vessels goes on in the manner described, but the greater bulk of the cut remains unprotected, and is readily penetrated by numerous wood-rotting organisms. Callus-production occurs in the region of the cambium, but many years may elapse ere the wound is covered, and during this period heart-rot may have set in. In the case of stone-fruits, the trees would almost certainly have become infected with silver-leaf. Thus it becomes a matter of necessity artificially to protect these wounds until such time as they may become occluded. This applies equally to all wounds of 25 mm. or more in diameter, for, although they may in time be protected efficiently by the plant, silver-leaf infection (as well as infection from numerous other fungi) may occur. For as has been shown under silver-leaf (p. 284), the majority of infections from this disease may occur within six months of the formation of the wound. Although the plant insulates itself against egress or ingress of water, this does not effectively bar the passage of certain fungous hyphae. Consequently with fruit-trees it is necessary that wounds be protected, whether made accidentally or purposely by man or other agency.

WOUND TREATMENT.

Wound treatment necessitates not only the painting over of the wounded surface, but also the treatment of the wound in such a manner as to facilitate occlusion. For it is well known that if a branch be cut back to within a few cm. of a larger branch, the stub so left does not callus over, but invariably dies back to the branch to which it is attached. Callus cannot form on such a stub, and the dead wood offers excellent opportunity for the penetration of wood-rotting fungi and boring insects.

The following treatments should obviate the danger of such infection from wound-fungi. Cut all dead stubs flush with the branch. Cut the bark above and below the wound, so that the whole assumes an elliptical shape, for this facilitates occlusion. Dress smooth all abrasions, removing rough portions of the bark with a sharp knife. Then paint with coal tar. If a branch is split at the crotch, it is advisable to remove it below the split, for little can

Fig. 15.

THIS PHOTOGRAPH ILLUSTRATES THE SLOW RATE AT WHICH WOUNDS ARE OCCLUDED.

The limb was removed from this tree by the author 14 years previously, and the cut then painted with red-lead. This shows the necessity for painting such surfaces with some protective substance.

Photo by Author.

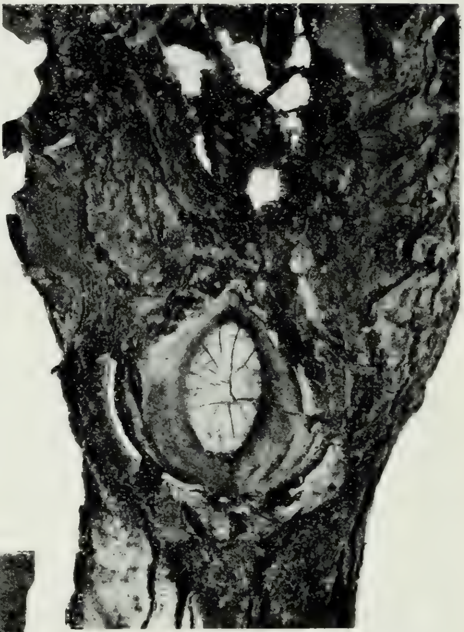

Fig. 15.

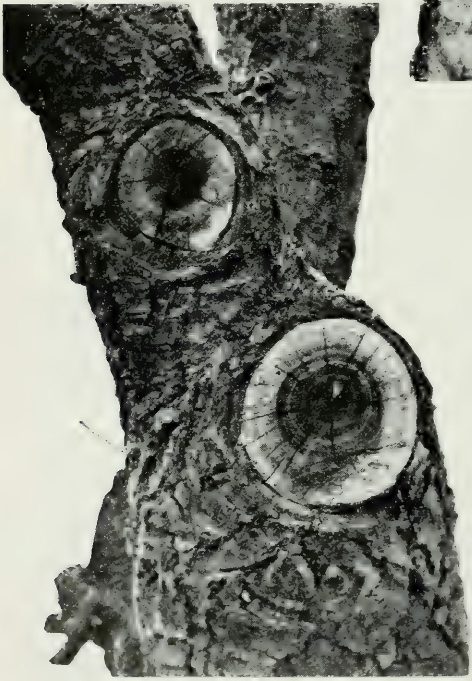

Fig. 16.

Fig. 16.

UNTREATED WOUNDS IN THE STEM OF AN APRICOT TREE.

Note the manner in which the exposed wood has become fissured.

Photo by Author.

be done with such an injury, and the split area forms an excellent opening for the penetration of fungi. In the case of a large limb being split at the junction with the stem, it may be possible to save the limb by bracing it to the main stem. For this purpose, bolts, carried through both, may be used. Or bore a hole through the affected branch a short distance above the split, and another through a branch opposite. In each insert an eye-bolt, being careful to countersink the nuts. Connect the two with a piece of galvanised wire. The bolts should preferably be of a diameter of 12 mm. (½ in.), and the bit used should be of the same diameter. It should be sharp and cut a clean hole. Both bolts before insertion should be dipped in coal tar, and when the nuts are in place the ends should be tarred so as to render them waterproof. Tar the exposed parts of the split; then fill the crevice with hot grafting wax.

Clean out all cavities penetrating the trunk, removing all discoloured wood. For this purpose a gouge, chisel, knife and mallet are all the tools necessary. Paint the exposed wood with coal tar. If the cavity is in an exposed position and tends to form a pocket in the wood, it is advisable to bore a hole into its base from the exterior, so that any water finding its way into the cavity may have an outlet. Treat this draining hole with coal tar. It is not necessary to fill the cavity with cement, for so long as the protective cover is kept intact, no decay will follow.

Coal tar is the most efficient of all wood preservatives used; for it functions as a disinfectant, a wood preservative, and provides an efficient surface covering, as, owing to its pliability, it is able to expand and contract slightly with the underlying surface, and thus does not crack to the same extent as white-lead paint or other substances so frequently recommended. It is often stated that coal tar has a detrimental effect on the bark, but this appears to have little or no foundation in fact, for the author has not as yet seen any injury to the tree follow from its use, even when, as frequently happens, the tar has run from the wound down the bark of branch or stem. The tar should be applied with a stiff brush, and well rubbed into the wood; and all wounds should be re-painted at least once a year until such time as they become occluded (Fig. 15).

TREATMENT OF CANKERS.

Another form of wound treatment is cutting out the cankers produced by such diseases as fire-blight, black-rot, etc. The treatment would depend on the size of the branch on which the canker were situated, for if the former were of small dimensions, it would be more efficacious to remove it, in which case the cut should be made well below the visible point of infection, preferably where the branch junctions with another.

If the canker were on the main limbs or stem of a large tree, then it would certainly pay to treat it in the following manner:—

With a draw-knife remove all the discoloured bark, so that the cankered area becomes exposed; then with a sharp knife, chisel, or gouge remove all the discoloured wood, cutting into the normal wood beyond the discoloured region. Then trim the wound in such a manner that it becomes elliptical or preferably fusiform in shape, the long axis of the wound running parallel with the branch.

It is advisable, and, in the case of fire-blight, essential, to sterilise such treated wounds. For this purpose use the following solution, which, on account of its penetrating qualities, is the most efficient of all those numerous compounds which have been recommended:—

Mercuric chloride	1 gram.
Hydrochloric acid (conc.) ..	15 cc.
Water	1000 cc.

This may, for the sake of convenience, be made up in stock solution by adding 20 grams of mercuric chloride to 300 cubic centimetres of commercial concentrated hydrochloric acid. For use, dilute 1 part of the stock solution with 60 parts of water. The stock solution will keep indefinitely, provided it is kept in a glass container.

Swab the wound with this solution, and after it has dried, paint over with coal tar. The success of this treatment depends entirely on the thoroughness with which the work is carried out, for if any diseased wood remains the disease may again become active, and the time expended be lost.

For literature references, see bibliography, p. 349, numbers *100, 101, 156, 167, 277, 325.*

CHAPTER IV.

FUNGI: THEIR MORPHOLOGY, PHYSIOLOGY AND REPRODUCTION.

Fungi; Structure; Vegetative Stage; Reproduction; Dissemination; Longevity of Spores; Physiology; Saprophytes; Parasites; Ectoparasites; Endoparasites; Infection; Polymorphism; Heteroecism.

Fungi are plants devoid of chlorophyll, the green colouring matter present in nearly all other plants: and this absence of chlorophyll is one of the principal features by which they are characterised.

In essentials all fungi consist of—

a. A vegetative part or stage.
b. A reproductive part or stage.

This division may better be illustrated by reference to such a fungus as the common mushroom. The whole of the part above ground, visible to the eye, consisting of cap and stalk, may be termed the fructification, for from it are produced the spores or bodies by which the fungus is reproduced. It may therefore be compared with the fruit of the apple, for the fruit also is the portion of the tree given over to reproduction.

In the soil, and therefore not visible, are countless minute threads radiating outwards from their point of attachment to the stalk of the fructification. These threads, or *hyphae,* as they will henceforth be termed (collectively they are spoken of as the *mycelium*), represent the vegetative stage of the fungus, for it is through them that all the necessary food substances are obtained. These substances are available as food directly they are taken into the hyphae, and so require no further elaboration. The mycelium, then, may be likened to the roots, stems, branches and leaves of a fruit-tree, for it performs somewhat similar functions.

Fungi being lowly plants, the high degree of differentiation of tissues acquired by the fruit-tree is wanting, the typical fungus in its essentials being reduced to two groups of organs—one, the vegetative, which obtains the necessary food substances; the other, the

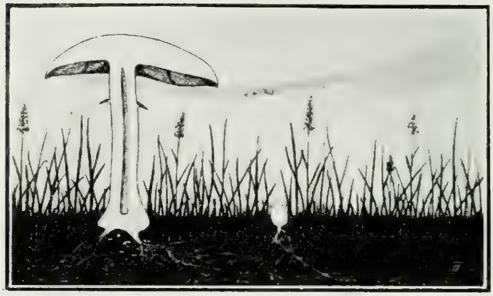

Fig. 16 *bis*. DIAGRAM OF THE FRUCTIFICATION AND MYCELIUM OF FIELD MUSHROOM (PSALLIOTA ARVENSIS). Reduced.

This shows the structure of the pileus and stem, the underground mycelium, spore cloud and (on right) young plant developing from the same mycelium.

After Buller (68).

reproductive, concerned only with the perpetuation of the species. Both may attain to a high degree of complexity, but fundamentally the fungus consists of these two groups only.

A large fungus, visible to the eye, has been chosen for this example, for the mushroom is known to all because of its size, abundance, and edible qualities. But the majority of fungi parasitic on fruit-trees are so minute as to be invisible, leading many growers, especially in the early days when diseases were little understood, to believe that "blights," as they were generally termed, were due to supernatural agency.

As a second example, circular-spot has been chosen. This disease forms minute, circular, ochraceous spots in the leaf of the apple. The infected cells, when examined, are seen to be brown and shrivelled, an indication that they are dead. Microscopic examination reveals the presence of numerous hyphae penetrating between these cells. After the cells have been killed, the fungus produces, from closely woven masses of these hyphae, small flask-shaped receptacles, named pycnidia, in which spores are produced. These pycnidia are exceedingly minute, and as they are produced within the dead tissues, are consequently invisible.

It becomes obvious that the difference between these two fungi is largely one of size, the large one being a well-known object, the other quite unsuspected, save for the formation of the leaf-spot. Another difference between the two becomes apparent in this discussion, for in dealing with the mushroom it was mentioned that its hyphae ramified in the soil, whereas the hyphae of circular-spot penetrated between the cells of a plant. The hyphae of the first fungus obtain their food-substances from decaying vegetable or animal matter in the soil; therefore it is spoken of as being a *saprophyte,* leading a *saprophytic* existence. The second, presumably, obtains its foods from the cells of the leaf, during which process it kills them; it is therefore a *parasite*, its mode of life being a *parasitic* one.

VEGETATIVE STAGE.

This, as has been shown, consists of fine thread-like hyphae, which penetrate the substratum, whether living or dead, and absorb therefrom the food substances necessary to their continued existence. Each hypha is usually tube-like, and in the majority of species is septate, a cross wall being produced at intervals within the tube, forming a series of cells. Each living cell consists of—

- *a.* Cell-wall
- *b.* Protoplast
  - Ectoplasm
  - Cytoplasm
  - Nuclei

as in higher plants, save that plastids are wanting. The cell-wall is usually composed of a substance termed fungus-cellulose, whose nature is still a matter of dispute. When first formed the cell-walls are hyaline, but in a great number of species the walls later become coloured some shade of brown, olive, or black. The inner wall of the cell is lined with the ectoplasm, which functions as in higher plants, governing the ingress and egress of solutes. Near the growing points of the hyphae the cells are usually completely filled with the protoplasts, but in older cells numerous large vacuoles appear, and in many the protoplast forms a thin layer closely adpressed to the wall of the cell, the central cavity being large and filled with cell-sap. In all cases the vacuoles are lined with ectoplasm.

The nuclei are usually very small, one, two or more being present in a cell; and in those species in which septa are absent, the hypha forming a continuous tube, the nuclei appear at intervals throughout its whole length, embedded in the cytoplasm lining the inner surface of the wall. Growth occurs at the apex of the hypha, and is continuous during its lifetime, save in those species in which the mycelium "hibernates" during the dormant season of the host. In many groups hyphae coalesce at the point of contact with one another, the cavities of the cells becoming continuous. No special significance is attached to this coalescence, although in certain groups it has been claimed to be a sexual phenomenon.

REPRODUCTION.

The spore on germination usually produces a hypha, which, by continued growth and frequent branching, gives rise to the mycelium. Exceptions occur, however, for certain lowly forms on germination produce another kind of spore. The mycelium develops until it has become well established, in or on the substratum, when it gives rise to certain structures from which spores are produced. These spores may be borne on naked, modified hyphae, or on structures enclosed within special receptacles. The spores may be one or many-celled, colourless or coloured, and may assume many shapes; in fact, classification of the fungi is based largely on the fructifications and spore characters. As there are about 80,000 described species, it may be realised what a tremendous number of forms is possible.

It is not proposed in this work to enter into a discussion upon classification, for this has only a technical bearing upon the problems of plant diseases, so that it will not be necessary to discuss the characters upon which certain classes, families or orders are based, nor to enter into the matter of asexual and sexual reproduction.

The simplest type of spore-bearing structure is met with in many moulds, and may be seen in powdery-mildew, where from the superficial mycelium is produced an upright hypha, or *conidiophore* (Fig. 73) from the free end of which conidia are abstricted. A short distance below the apex a septum is formed, which cuts off a portion of the hypha together with its contents; this may become free by breaking away at the septum from the point of attachment, or, as usually happens in this species, may persist for some time, other spores being formed below in a similar manner until a chain of conidia is produced. Conidiophores frequently branch, and each branch may produce conidia, so that in this manner many diverse forms may arise. Or they may become loosely interwoven, and slightly elongated, giving rise to a pedicel-like structure known as a *coremium.* Frequently the hyphae become intricately interwoven, forming a tissue resembling the cellular structure of higher plants, to which the term *stroma* is applied. If the stroma be comparatively small in size, and produces from the upper surface numerous short conidiophores arranged in a palisade manner, an *acervulus* is formed (Fig. 29); if the basal portion of such a structure be well developed, forming a cushion-like base, it then becomes a *sporodochium.*

When hyphae become interwoven so as to form a hollow, globose, or flask-shaped receptacle, on the inner surface of which spores are produced on short conidiophores, the structure is known as a *pycnidium* (Fig. 57); should the spores be borne in sacs (asci) within a similar receptacle, it is then termed a *perithecium* (Fig. 45), in order to differentiate it from a pycnidium. These structures may open to the exterior by a minute apical pore, or *ostiolum,* or may be without this opening. The ostiolum may be in the centre of a small depression in the apex of the receptacle, when it is said to be *umbilicate;* if the ostiolum is in the centre of a small nipple-like projection on the apex of the receptacle, it is termed *papillate;* and so on. The structure of the fructifications becomes more complex when the pycnidia or perithecia are embedded in a stroma, for then we may find many closely compacted together, opening by separate ostiola, or by a single opening common to all. Further, each receptacle may be divided by septa into numerous *loculi.*

In this way we can trace the gradual development from the simplest to the most complex type of fructification. If a perithecium were cut in half by an equatorial incision, we should obtain a structure not unlike an *apothecium,* a structure that may be stalked or sessile. In one class of fungi, the Basidiomycetes, quite large structures are frequently found. These, as in the field mushroom, may consist of cap (pileus) and stem. On the under surface are produced the gills, covered with the spore-bearing layer. Other types may be found appearing as shelf-like growths on the sides of tree trunks, the underside of such structures consisting of numerous stratified tubes. These large structures are composed of innumerable closely interwoven hyphae; and the spore-being portion, or hymenium, covering the gills or lining the pores, consists of numerous club-shaped *basidia* arrayed in palisade manner. From the apex of each basidium projects a variable number (usually 4) of slender, spine-like processes or *sterigmata* (Fig. 151), on which the spores are borne. These spores (basidiospores) develop on the sterigmata, and when mature fall away.

In the Ascomycetes, the spores are contained within hyaline envelopes, or asci (Fig. 35). These are formed singly at the ends of hyphae, by the inflated terminal end of the hypha being cut off by a septum. Within this cell the nucleus divides repeatedly until the number of nuclei produced corresponds with the number of spores to be formed. Then around each nucleus a wall develops, enclosing it, together with portion of the cell-contents. The method varies with the species, but further details need not be entered into here.

DISSEMINATION.

The spores may thus be produced on conidiophores exposed to the air, on basidia on the gills or tubes of certain Basidiomycetes, or in pycnidia or perithecia on or in the substratum. When exposed to the air, the spores may be detached and carried by the wind or by insects to some suitable locality, where they may germinate should conditions prove favourable. In general, the spores of Basidiomycetes are produced on structures so oriented that they may fall vertically from the sporophore. Once free, they may be caught and carried by air currents. In the case of spores contained within pycnidia, they are usually carried to the exterior in gelatinous

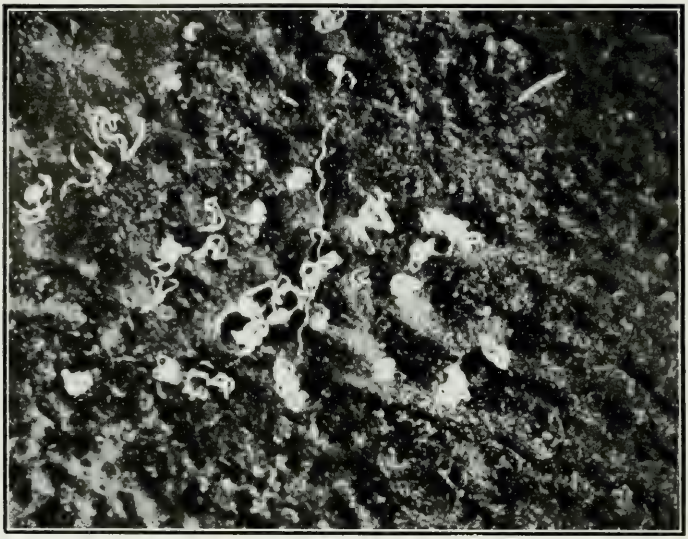

Fig. 17. SPORE TENDRILS. × 20.
These gelatinous tendrils have been forced through the ostiola of pycnidia embedded in the host tissues. *Photo, H. Drake.*

tendrils (Fig. 17). Certain tissue at the base of the pycnidium becomes converted into a gelatinous substance. This, in the presence of moisture, swells and exudes through the ostiolum to the exterior, carrying with it the spores. The tendril is soft and slightly viscid, consequently portions may readily be carried to some distance by birds or insects. When deposited on some surface, the mucilage may be dissolved by rain and the spores freed to be further dispersed by wind or rain splashes, or else to germinate *in situ.* Doubtless a great number of such tendrils produced from receptacles in leaves or branches of a tree are washed by rain to lower branches and leaves, for their appearance would to a large extent coincide with rainy weather, owing to the property possessed by the mucilage of absorbing water.

A similar method of spore discharge is common to certain Ascomycetes. Many of the latter, however, possess a mechanism whereby the spores are ejected from the asci (in perithecia or apothecia) with sufficient velocity to carry them several cm. (up to 30 cm. has been recorded [*68*]) into the air, where they may be caught and carried by air currents to some distance from their place of origin. Certain pycnidia and perithecia do not possess ostiola; in many of these dehiscence is circumscissile, but with the majority, decay of the enclosing receptacle is the only means whereby the spores are released.

Certain fungi are capable of producing motile spores in the presence of excess water. Such an example is the organism causing citrus brown-rot; this fungus produces sporangia, from which (in water) are discharged numerous zoospores —one-celled conidia with flagella—which swim about in the film of moisture covering the host tissues. Later they settle down, lose their flagella and germinate, each producing an infection-hypha.

No data are available as to the distance spores may be carried by wind or by insects. Buller *(68)* found that the rate of fall of spores in still air varied according to size, from 0.5 to 5 mm. per second. On the other hand, Stakman *et al (292)*, by exposing from aeroplanes glass slides smeared with vaseline, found spores, pollen-grains, glumes of grasses and small insects to be abundant up to 3,550 m. (11,000 ft.). For example, on one slide exposed five minutes at 2,438 m. (8,000 ft.), 827 spores of known identity were caught, and in addition 200 unknown. Even at 5,029 m. (16,500 ft., more than 3 miles high), some spores were obtained. Many caught at lower levels were found to germinate readily. Thus it appears probable that under certain conditions spores may be carried to long distances by wind, and may be brought to earth by rain, but no data are available as to whether these spores are capable of infecting plants. The matter will be further dealt with under dissemination of diseases.

LONGEVITY OF SPORES.

In general, thin-walled spores do not remain viable for any length of time, and exposure to sunshine or dessication tends to shorten this period. Others, again, especially certain thick-walled forms, are capable of remaining viable for several seasons. In certain species a special coat is secreted, apparently to enable the spore better to withstand extremes of heat or cold. Various structures assist to retain spore vitality, for both pycnidia and perithecia appear to function in this manner. Then, too, certain species are able by the production of special thick-walled spores (chlamydospores) to tide over unfavourable conditions. These spores may be produced in numerous ways, one of which is from vegetative hyphae. Certain hyaline hyphae become multiseptate; the cells thus formed become greater in diameter, the walls increase in thickness and darken in colour, probably through the infiltration of some substance impervious to moisture. These structures may then rest for a time, and, conditions becoming again favourable, germinate and produce hyphae in the usual manner. A not uncommon method of resisting an unfavourable period is by the production of sclerotia. These are

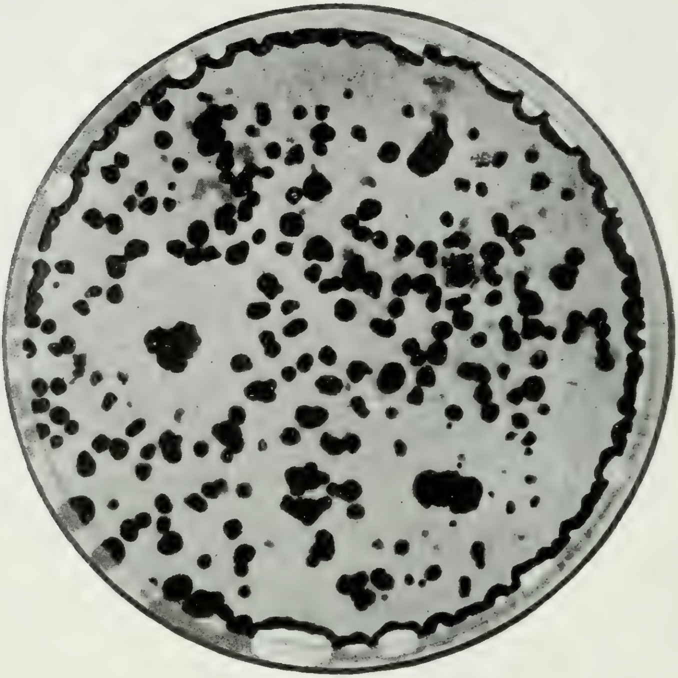

Fig. 18. SCLEROTIA OF BOTRYTIS-ROT. Natural size.
These sclerotia have appeared upon culture media in a petrie dish.

Photo, E. Bruce Levy.

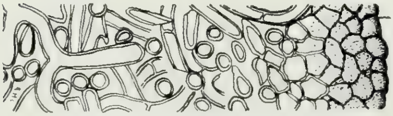

Fig. 19. SECTION OF SCLEROTIUM SHOWING PSEUDO-PARENCHYMATOUS WALL AND HYPHAE WITH THICK, PARTLY GELATINISED WALLS. × 300.

Original.

compact, closely interwoven hyphal masses (Figs. 18, 19). The lumen of each hypha within the mass is filled with reserve food, usually as globules of oil, etc., and the periphery of the mass becomes dark in colour and somewhat cellular. These bodies may resist dessication for as long a period as ten years, at the end of which time they may produce special fructifications bearing asci, or may again produce hyphae.

PHYSIOLOGY.

All food substances required are taken into the cells in solution. Naturally the procedure of obtaining such foods differs according to the substratum upon which the fungus is growing, and to whether the species is saprophytic or parasitic. As fungi lack chlorophyll, they cannot elaborate these foods, so of necessity obtain them from living or dead animal or vegetable tissues. Without going into the matter further, it may be said that hyphae have the property of being able to secrete certain substances (enzymes), which vary according to the species (or even the individuals), and that this substance or substances may act upon living or dead tissues in such a manner as either to render them soluble or else to render them in a condition suitable for further breaking up by other enzymes.

It has been mentioned that fungi may be parasitic or saprophytic, according to whether they live upon living or dead plant or animal tissues. The parasitic fungi may further be subdivided, according to whether they are true or *obligate* parasites, such as the rusts, which are able to live only on living tissues, and cannot be grown on culture media; or the *hemiparasites,* which for part of their life-cycle are parasites, part saprophytes. The saprophytes may be true saprophytes, able to live only on dead tissues, or hemisaprophytes, living normally as saprophytes, but becoming parasitic on occasion. This may be shown graphically as follows:—

SAPROPHYTES.
    Hemisaprophytes.

PARASITES.

$$\left.\begin{array}{l}\text{Obligate parasites.}\\ \text{Hemiparasites.}\end{array}\right\} \times \left\{\begin{array}{l}\text{Ectoparasites.}\\ \text{Endoparasites.}\end{array}\right.$$

Saprophytes, together with saprophytic bacteria, are Nature's scavengers, for they effectively break up and release from dead plant and animal tissues the chemical substances stored therein.

Hemisaprophytes may pass through their life-cycle on dead matter, or, under favourable conditions (to them) may become weakly parasitic. For example, the fungus causing coral-spot is commonly found as a saprophyte on dead prunings, yet under certain conditions it may become parasitic. Should a spore of this species be carried to a dead lateral of a living tree, it may germinate and give rise to a mycelium which lives for a time saprophytically on this dead wood; the hyphae gradually spread to the living tissues, where they appear to penetrate the xylem vessels, blocking them and preventing the upward passage of water; consequently the branch wilts and dies, when the hyphae spread into the dead tissues and again live saprophytically.

Parasites may be obligate or true parasites, able to attack only living tissues, or may be hemi-parasites, living for a time parasitically, for a time saprophytically, but part of the life-cycle (usually the first stage) must be parasitic. To the hemi-parasites the greater number of pathogenic species belong.

These two groups are further subdivided into ectoparasites and endoparasites, according to the manner in which they derive from the host cells their necessary food substances.

Ectoparasites.—To this group belong those fungi known as mildews. The whole of the vegetative and reproductive portions of such fungi are superficial, growing on the surface of the host. The food substances are taken from the host in the following manner:—From hyphae in contact with the host are produced small lateral branches, each of which penetrates the epidermis, by the secretion of a solvent of the cell wall, and enters one of the living epidermal cells. Here it swells at its tip, forming a vesicular body, termed a *haustorium,* which abstracts food materials from the cell.

Endoparasites.—To this group belong those fungi the hyphae of which penetrate into or between the host cells. The great majority of species are included in this group. On germination of the spores, the infection-hyphae penetrate into the host tissues, and there branch repeatedly to form a mycelium. The hyphae may grow through the intercellular spaces, and send haustoria into the cells, as in the rusts. The hyphae do not always kill the cells, but frequently stimulate them to excessive division, so that malformed host-tissues are produced. With the fungus causing leaf-curl, the hyphae force their way between the tissues of the cuticular layer and by endosmosis absorb their necessary foods. No haustoria are sent into the cells. This species stimulates the host cells to active division, and curled and distorted leaves result. Other species, as the brown-rot organism, may send hyphae between the cells, killing them as they advance, by the secretion of certain substances toxic to the cell protoplast; others, again, send their hyphae directly through the cells, causing their death.

INFECTION.

The manner in which fungi penetrate living tissues differs according to the species and its habitat. For example, it is obvious that ectoparasites, being superficial, need only penetrate the host tissues with the minute structures which develop into haustoria. With the greater number of endoparasites, penetration is effected in various ways. For example, hyphae may grow directly through the stomata, as with the infection-hyphae of the uredospores of many rusts; others may penetrate directly through the epidermis into the living cells beneath, as in the case of the shot-hole organism; others, again, may penetrate through the lenticels to the cortical cells beneath the bark, as with the fungus causing blister-disease. Still others are able to penetrate through some injury in the epidermis exposing the succulent tissues beneath, as, for example, the blue-mould fungus; or through some abrasion or injury in the branch, as does the fungus causing silver-leaf. Still others must develop saprophytically a copious mycelium in dead tissues ere they are able to penetrate to healthy tissues, as, for example, the coral-spot fungus.

Moisture in some form is necessary to the early establishment of the fungus upon its host; in fact, many spores will not germinate unless immersed in water; others, again, will germinate in a saturated atmosphere. This is well illustrated by the prevalence of black-spot in the low-lying portions of districts in which the disease is present.

POLYMORPHISM.

Many species of fungi produce more than the one spore-form in their life-cycle, this phenomenon being known as polymorphism. For example, if a single conidium of the fungus causing diplodia-canker be sown on suitable culture media, it will give rise to a mycelium, which produces pycnidia containing one-celled, colourless conidia. As the culture ages, in the same or separate pycnidia, the conidia change to a dusky olive colour, and after long keeping become uniseptate.

A better example occurs in the cycle of the fungus causing leaf-rust of stone-fruits. If teleutospores are caused to germinate in water, they produce basidia bearing basidiospores. Should these be sown under favourable conditions upon young leaves of certain species of cultivated *Anemone,* they may produce small cup-shaped structures containing numerous chains of orange-coloured aecidiospores. If these in turn are caused to infect the young leaves of (say) the plum, they produce pustules of uredospores; and late in the season from the same substratum may be produced teleutospores. Thus no less than four spore forms are produced by this one fungus, namely, basidiospores, aecidiospores, uredospores and teleutospores.

This especial fungus also exhibits another peculiarity, found in several other species of the group to which the rusts belong. For the complete cycle is carried out on two separate hosts, widely separated botanically, one belonging to the family Ranunculaceae, the other to the Rosaceae. The basidiospores produced by the germination of the teleutospores from the plum leaf will infect only the leaf of *Anemone* (or *Thalictrum*), for they are incapable of infecting the leaves of stone-fruits, whereas the aecidiospores produced on the *Anemone* will infect only stone-fruits and cannot infect other plants of *Anemone*. This peculiarity of requiring two hosts for the completion of the life-cycle is known as *heteroecism*.

For literature references, see bibliography, page 349, numbers *68, 72, 131, 150, 152, 155, 206, 207, 271, 292, 316.*

CHAPTER V.

BACTERIA.

Structure; Reproduction; Motility; Prototropic Bacteria; Metatropic Bacteria; Paratropic Bacteria; Infection; Effects upon Tissues; Perpetuation.

Bacteria are extremely minute, lowly plants. They are usually unicellular, and, like the Fungi, are without chlorophyll.

STRUCTURE.

There is a definite colourless or coloured cell-wall which is of unknown composition, but would appear to be chemically allied to living protoplasm. Chitin has been demonstrated in the cell-walls of certain forms. The cell contents consist of protoplasm, but no definite nucleus is present. An ectoplasm has been demonstrated in certain of the larger forms. One or more granular chromatin bodies are present in the protoplast, but their function is unknown; they have been regarded as nuclei by several authorities.

Members of this class may be spherical, rod-like, allantoid, curved, filamentous or spiral.

REPRODUCTION.

This is accomplished vegetatively by active fission in one or more planes; an organism may increase in size, and become divided by a transverse septum. The daughter cell may then become free or persist, in which latter case chains or cubes are formed. Sometimes the cell-wall or membrane of these forms undergoes partial gelatinisation, the numerous chains becoming embedded in the mucilage, forming a raft-like structure termed a *zoogloea*. Reproduction may proceed with great rapidity, for division in one species is known to occur under favourable conditions once in every 20 minutes; in another, once in 30 minutes.

Certain species, when unfavourable conditions arise, are capable of forming spores. These may be *arthrospores,* which are simply cells in which the walls have become thickened; or *endospores,* which are formed in the centre or near one end of the cell by the inner portion of the protoplasm separating from the wall of the cell and surrounding itself with a thick membrane. Sometimes two endospores may be produced within the one cell. These are capable of resisting extremes of heat and cold, and thus serve to tide the species over unfavourable conditions. On the resumption of favourable conditions, the spore membrane becomes dissolved and the contents freed. Spores are absent from certain groups.

MOTILITY.

Certain bacteria are provided with delicate cilia or flagella, by the vibration of which they are able to move about in the media in which they happen to be present. These organs differ in position with different species, for a single flagellum may occur at one pole or at both; a tuft may be present at one or both poles; or cilia may cover the entire surface.

Numerous methods of classifying members of this class have from time to time been proposed, but this matter need not be discussed here. It may be mentioned, however, that they have been grouped according to their method of nutrition, as under:—

Prototropic = those requiring no organic compounds for their nourishment.

Metatropic = Saprophytes. } = those requiring organic compounds.
Paratropic = Parasites. }

Prototropic Group.—This includes such organisms as the nitrifying bacteria, root-nodule bacteria, sulphur bacteria, and iron bacteria.

Metatropic Group.—Under this heading are included those bacteria which are utilised in the manufacture of acetic acid from alcohol; those which convert milk-sugar into lactic acid, widely used to-day in milk "starters" for the manufacture of cheese. Here also are included those bacteria which break up the stored chemicals in dead animal and vegetable matter and render them available for use by plants. Their work is essential, otherwise all foods taken from the soil by plants would in time become locked up, as it were, in dead tissues.

Paratropic Group.—Under this group are included all those bacteria parasitic upon animals and plants. Of bacterial diseases of animals, no mention need be made, for this matter does not concern us here. That bacteria are able to cause diseases of plants has but recently become well established, for the first proof was not forthcoming until Burrill *(20)* in 1880 established beyond doubt that fire-blight was of bacterial origin. To-day several score of bacterial diseases are known, several of which attack fruit-trees. Fortunately, only two of these—fire-blight and root-knot—are known to occur in New Zealand.

INFECTION.

Bacteria may penetrate into healthy plant tissues through some superficial injury or through the stomata, water pores, lenticels, or directly by way of the flowers. In penetrating through injuries, it is probable they are first carried to the injured surface by insects, birds, or possibly in rain drops. In many cases, indeed, they are carried with the insect responsible for the injury. For it has been well established that leaf-hoppers may spread fire-blight by feeding first on tissues infected with this organism, then visiting healthy shoots, puncturing these in turn, and depositing numbers of the organisms in the injury thus formed. Bacteria may enter stomata or water pores by first becoming established in exudates in the vicinity of these structures, and gradually spreading to healthy tissues, killing first a few cells, and then spreading from this initial infection area. They may also be deposited by insects in the fluid within the nectaries. Here sufficient food is present in the nectar to enable them to live for a time saprophytically. They may thus become established and gradually penetrate the host tissues, killing and blackening the calyces. From these initial points of entry the bacteria may spread to the healthy tissues, effecting penetration between or through the cells in a manner similar to fungi, i.e., by the secretion of enzymes which disintegrate the tissues.

EFFECT ON THE TISSUES.

Bacteria may attack the living parenchyma, which they finally convert into discoloured rotted areas, visible as spots or rots on the affected tissues; or, as frequently happens, they may gain entry to the vascular system (as in fire-blight), with the result that the vessels become stopped, upward passage of water ceases, the leaves wilt, and the stem and leaves die. In this manner the organisms may be rapidly distributed throughout the tissues of the host. Their presence may not cause the death of the cells, but may stimulate them to excessive proliferation. Such an example occurs in root-knot, where in the course of years tumours of a large size may be produced. Or they may have a partly solvent, partly rupturing action (owing to their increase in bulk, due to increase in numbers) on the middle lamellae, causing the disruption of the affected tissues.

PERPETUATION.

As previously mentioned, bacteria may produce spores capable of remaining viable for a considerable period. In this form they may persist for years in dead tissues or in the soil. Others, such as the fire-blight organism, are not known to produce spores; but as this species is able to remain in infected tissues throughout the winter months, it would appear to be able to "hibernate" over this period, a belief strengthened by the fact that this species has been known to remain viable for nine months in dried ooze *(319)*.

CONCLUSION.

Bacteria have become widely recognised mainly because of the diseases they produce in man, less so because of diseases of other animals. But to the layman it is too frequently unknown that they play any other part in nature. Hence the foregoing examples have been chosen to show what a tremendous economic part they do play. It may be safely asserted that crop production would be an uncertain practice were it not for the soil bacteria, for, as has been shown, they, together with certain fungi, play an important role in agriculture, releasing as they do all available plant foods that would be otherwise indefinitely locked up in dead plant and animal tissues. To-day, bacteria are utilised largely in the industries; for example, in cheese-making, the manufacture of acetic acid, the retting of flax, curing of tobacco, and production of ensilage. Incidentally, it may be mentioned that the frozen and canned meat and vegetable industries have arisen indirectly through their activities.

For literature references regarding bacteria, see bibliography, p. 349, numbers *29, 70, 200, 243, 281, 282, 283, 319, 320.*

CHAPTER VI.

DISEASES OF PLANTS.

Distribution; Local Distribution; Susceptibility and Immunity of Hosts;
Tables of Varietal Susceptibility;
Losses Due to Plant Diseases.

A plant may be considered to be diseased when its normal functions or development are in some manner checked, or thrown out of equilibrium. Such a condition or conditions may be brought about by many different agencies, which it is usual to group under the headings—

Insect Pests.
Fungous Diseases.
Bacterial Diseases.
Physiological Diseases.

Insect pests lie without the province of this book, so need not be further referred to save where their control is discussed in connection with the use of dual sprays.

The symptoms set up in the hosts by diseases are practically the only guide the orchardist can rely upon to determine the nature of a trouble affecting his trees. To facilitate diagnosis, the section dealing with symptoms has been placed on p. 101, preceding the artificial key to the diseases of pome-fruits.

DISTRIBUTION.

Under this heading will be considered only those diseases induced by pathogenic fungi and bacteria. With one exception (root-fungus) all the diseases attacking fruit-trees in New Zealand have been introduced from other countries; for, although no exact data in the case of several are available, it would appear that seven diseases have been introduced from Europe and or North America, twenty-three from Europe, six from North America, three from Australia, and one is endemic.

It is obvious that these diseases must have been introduced by man with nursery stock. In the early part of last century the first European fruits were brought into New Zealand by the missionaries. These were mostly introduced by means of the seeds (stones and pips); thus trees were for long free from most of the diseases known to attack them to-day. In the warmer parts of the Dominion these trees throve and were spread widely, partly by the Maori, partly by the white man, and no doubt partly by animals and birds. This is evidenced by the fact that the "Maori" peach—a seedling white-fleshed freestone, of large size—was in the 'seventies wide-spread throughout the North Island. About 1882 two European diseases—die-back and leaf-curl—became established in localities where these trees were plentiful, and in 1889 the "Maori" peach was practically exterminated. It would appear that in the early days of last century fruit-trees would likely perish during the long sea voyage in sailing ships, so seeds only of cultivated plants were brought from Europe; but when steam navigation became universal, young trees were imported with their accompanying diseases, so that in the Dominion to-day are present practically all fruit-tree diseases that are wide-spread in Europe and North America.

In a number of instances it would be impracticable to determine the presence of disease on nursery-stock while in the dormant stage, so that inspection of such stock at the ports of entry is not an efficient safeguard against the introduction of fungous or bacterial diseases.

Once a disease has been introduced, it may be distributed to local areas by infected nursery stock, and from these spread in various ways to orchards in the vicinity; or should young trees be introduced into a single nursery, they may carry diseases which may spread to other young trees in the vicinity, and the disease or diseases become widespread by the distribution of such trees.

LOCAL DISTRIBUTION.

The extent of the local distribution of a disease is governed by numerous factors, such as temperature, rainfall, abundance of the host, methods of dissemination, etc. In so far as New Zealand is concerned, temperature plays only indirectly any part in distribution, that is, by limiting certain hosts to certain localities. For instance, commercial citrus-fruit culture is limited to the northern part of New Zealand, consequently citrus diseases are also confined to these localities. It may to a certain extent have a limiting effect on the distribution of bitter-rot, for this disease is prevalent in the orchard only in the Auckland province, but this appears to be nullified by its prevalence in cool-store throughout.

The effect of rainfall on the distribution of a disease may not appear noticeable where the annual rainfall is over 25 inches, for only one locality in New Zealand has an average rainfall less than 20 inches, and this is the only locality in which diseases exhibit any peculiarity of distribution. In Central Otago, fruit-growing is confined to the districts of Ettrick, Roxburgh, Alexandra, Clyde and Cromwell. These areas lie in the valley of the Clutha River, and are surrounded by mountainous country. Both black-spot and brown-rot are absent from Cromwell, Clyde and Alexandra, but are present in Roxburgh and Ettrick. Unfortunately, the rainfall records for these localities are incomplete, so that little direct evidence can be brought to bear on the matter of the distribution of these two diseases; but from the following table it will be seen that there is a difference of several inches between the areas in which these diseases are present or absent.

TABLE OF RAINFALL IN CENTRAL OTAGO, FOR 1922-23, IN INCHES.

	1922.	1923.
Clyde	15.37	15.13
Alexandra	13.16	12.76
Roxburgh	18.34	21.72

Precipitation may be the governing factor, but no method of measuring the annual precipitation is in use in any of these localities. The presence of moisture, as has been pointed out, is necessary to effect germination of the spores of fungi, so that where the atmosphere is dry, infection cannot occur, save through exudates from injured tissues.

The relative abundance of the host is a factor that plays an important part in the distribution of a disease; for in a sparsely populated area, where farms or orchards are few and scattered, it may be many years before a disease becomes dispersed through the district. This, again, would depend on the method of dissemination of the disease; were the disease a fungous one, and the spores light and capable of being wind-borne, it would quickly become widespread; whereas if the disease were insect borne, its spread would be limited by the distance of flight of the insect-carrier. This is well exemplified in the distribution of fire-blight in the Auckland

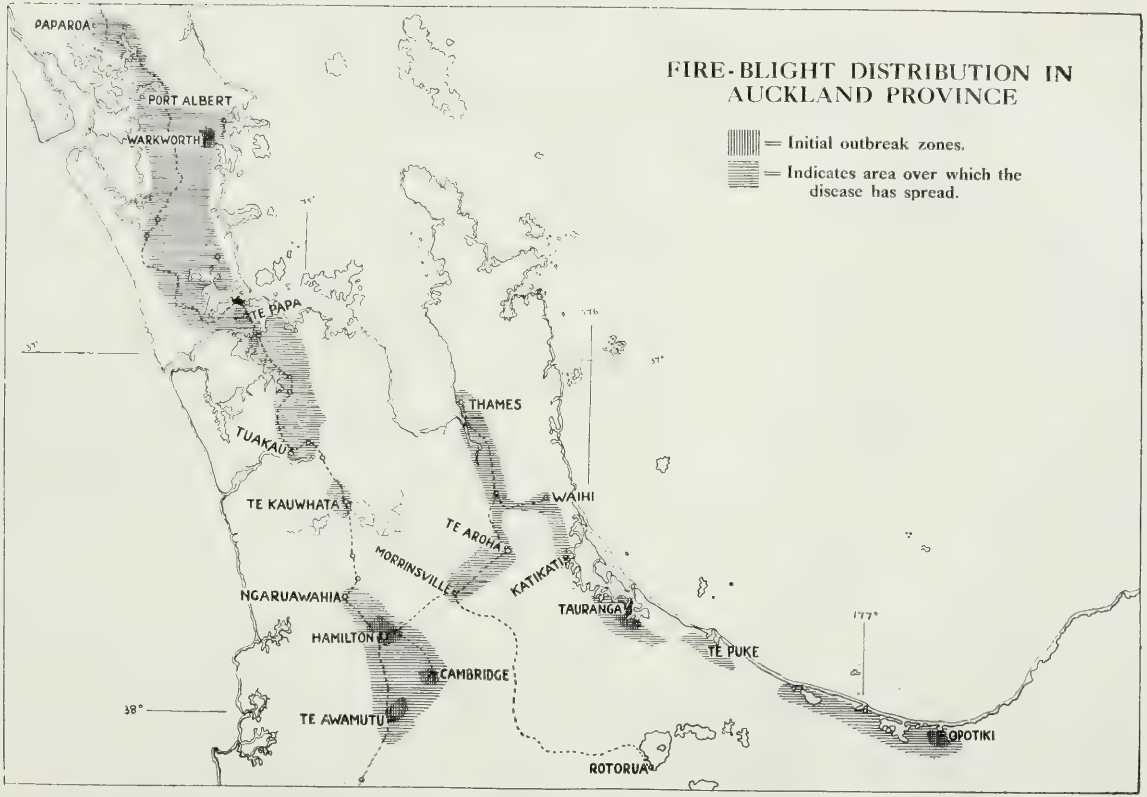

Fig. 20. DETAILED MAP OF FIRE-BLIGHT DISTRIBUTION IN THE AUCKLAND PROVINCE.

Original,

province. In the accompanying map (Fig. 20) the vertical lines indicate the areas of initial outbreak; the lateral lines indicate subsequent distribution. This distribution has largely been augmented by the fact that the hawthorn has proved a suitable host for the fire-blight organism, with the result that wherever this plant, together with pome-fruit orchards, have formed a continuous area fire-blight is prevalent throughout that area, for this disease is dependent for its spread upon insects, such as honey-bees. The discontinuous nature of the zones in which fire-blight is present is due to the absence of hawthorn hedges and homesteads with small pome-fruit orchards. The disease has spread throughout practically the whole of the territory in which its hosts abound (that is, within the distance insects are able to travel), for the fire-blight-free areas on the map are for the most part sparsely populated. Consequently, unless the disease is introduced by man into other areas (as has in all probability been done in the case of the Whanganui and Wairarapa outbreaks), it is unlikely that it will spread further.

The methods of dissemination of bacteria or of fungi largely govern the distribution of diseases. For, as has been shown, fire-blight in any one area is spread by insects, and in consequence the distance of flight of those insects is the limiting factor in the spread of this disease. Similarly are limited those fungous diseases disseminated by insects. Prevailing winds may carry for considerable distances spores of certain fungi, but no evidence is available showing such to be the case. Local distribution may be a slow process in the case of those fungi dependent on the dissemination of their spores in rain-splashes, for it may take such a disease several seasons to spread through a single orchard. Birds may play a part in the spread of certain fungous diseases. For instance, spore tendrils of valsa-injury and similar fungi may become attached to their feet when birds alight upon a branch, and carried thus to some other tree, where they may become deposited, the spores afterwards being freed from the mucilage by rain. Then, too, they readily may spread such diseases as brown-rot by piercing alternately with their beaks diseased and healthy fruits.

SUSCEPTIBILITY AND IMMUNITY.

It has been shown that many diseases are capable of penetrating the host tissues only through some injured surface; thus when trees are subjected to rough treatment, or are planted in a locality exposed to high winds, they may suffer to a greater extent from wound parasites. This would also be the case if they were grown on light or poorly drained land, or damaged through faulty irrigation, for weakened growths would be present on such trees, offering greater facility for the penetration of this class of organism.

Again, faulty handling and storage of fruits would tend to render them more susceptible to the penetration of certain fruit-rotting fungi. In fact, any factor lowering the vitality of the host would tend to render it more susceptible to infection.

Certain plants prove highly susceptible to attacks from disease; others, again, prove to be resistant or even immune. This matter is not fully understood, but it would appear that resistance may be largely an anatomical or physiological feature possessed by certain species, varieties or even individuals. Thus it is well known to orchardists that certain varieties of (say) peach are seldom infected with leaf-curl, whilst others suffer severely. Such structures as the hairs on the leaf or fruit may tend to lessen infection from certain diseases. For example, with peach-scab, infection as a rule does not occur until the mat of hairs covering the fruit has become considerably weathered, whereas the hairless nectarine may be infected at a much earlier stage. Again, Valleau *(306)* has shown that certain varieties of plums are resistant to brown-rot, because the stomata early become plugged with masses of parenchyma, and penetration of the infection-hyphae through these openings is thus prevented. Mouldy-core infects only those apples possessing an open calycine sinus, through which are carried the spores of the fungi causing this condition. Similarly, "bloom" on the skin of fruits often prevents the penetration of fungi.

Certain pathogens are capable of attacking numerous hosts; as for example, silver-leaf occurs on numerous hosts belonging to many families; others, again, are limited in their infection capabilities to the one host. For example, black-spot and pear-scab are closely allied, yet each cannot infect the host of the other. Then, too, different varieties of the one host show varying degrees of susceptibility, but this is a variable quality, for a variety resistant to a disease in one locality may be highly susceptible in another. Thus the apple variety Yates is resistant to black-spot in Otago, yet highly susceptible in Nelson. So that it becomes a difficult matter to compile a list of varieties susceptible or resistant to individual diseases. However, certain varieties appear to be more or less constant in this respect, and these are listed in the following tables, compiled from data supplied by the Orchard Instructors of the Department of Agriculture:—

TABLE OF VARIETAL SUSCEPTIBILITY (Pome-fruits).

Disease.	Hosts.		
	Highly Susceptible.	Moderately Susceptible.	Resistant.
Black-spot	Cleopatra Delicious Dunn's Favourite Newton Pippin Rome Beauty	Adam's Pearmain Ballarat Cox's Orange Pippin Gravenstein Jonathan Northern Spy Spitzenburg Statesman Sturmer Pippin	Reinnette du Canada Scarlet Nonpareil Shiwasse Beauty Takapuna Russet Worcester Pearmain
Pear-scab	Glou Morceau Louise Bonne d'Jersey Packham's Triumph Vicar of Winkfield Williams' Bon Cretian Winter Nelis	Beurre Bosc Beurre Clairgeau Beurre Diel Beurre Hardy Fertility P. Barry Winter Cole	Conference Keiffer's Hybrid Twyford Monarch
Powdery-Mildew	Cleopatra Cox's Orange Pippin Jonathan London Pippin Lord Wolseley Northern Spy Rome Beauty	Ballarat Docherty Dunn's Favourite Gravenstein Newton Pippin Statesman Sturmer Pippin	Delicious McMahon's White Reinnette du Canada Scarlet Nonpareil Worcester Pearmain
Bitter-pit	Cleopatra Cox's Orange Pippin Lord Wolseley Ribston Pippin Sturmer Pippin Yates' Seedling	Ballarat Dunn's Favourite Jonathan London Pippin Newton Pippin Rome Beauty Spitzenburg Statesman	Delicious Dougherty Gravenstein Irish Peach Reinnette du Canada Takapuna Russet Worcester Pearmain
Glassy-core	Adams' Pearmain French Crab London Pippin Lord Wolseley Pioneer Scarlet Pearmain Statesman Stone Pippin	Ballarat Cleopatra Delicious Dunn's Favourite Newton Pippin	All other varieties
Mouldy-core	Cleopatra	Delicious Yates' Seedling	All other varieties

TABLE OF VARIETAL SUSCEPTIBILITY (Stone-fruits).

Disease.	Hosts.		
	Highly Susceptible.	Moderately Susceptible.	Resistant.
Bladder-plum (plums)	Burbank Ogon Satsuma	Botan Czar Evans' Early Okararu Sultan	All other varieties
Brown-rot (peaches)	American Champion American Pound Briggs' Red May Hales' Early Muir Peregine Ruby Red Triumph	All other varieties	Carmen Lady Palmerston Mamie Ross Phillips' Cling Pullar's Cling Sneed Wiggins
Brown-rot (plums)	Angelina Burdett Blue Diamond Yellow Diamond Yellow Magnum Bonum	All other varieties	Admiral Togo Combination Doris Giant Prune Hale Satsuma Sultan Wright's Early
Brown-rot (nectarines)	Goldmine Jean de Padua New White	All other varieties	Early Rivers Hunt's Tawny Irrawarra
Brown-rot (apricots)	Oullin's Early Roxburgh Red Royal Tilton	All other varieties	Bolton Newcastle
Leaf-curl (peaches)	Elberta Kalamazoo Paragon Triumph	All other varieties	Golden Queen Hobbs' Late Sneed Solway
Leaf-rust (peaches)	Lady Palmerston Late Crawford Muir Royal George Solway Triumph	All other varieties	Carmen Gold Dust Gold Queen Sneed Wiggins
Leaf-rust (plums)	All English varieties	—	All Japanese varieties

LOSSES DUE TO PLANT DISEASES.

The following figures, taken from the United States Department of Agriculture Plant Disease Bulletins *(12, 14, 16)*, give estimated crop losses due to plant diseases in that country. Their method of calculation is as follows:—

Actual production is taken to represent 100% minus the sum of the percentages of loss from all diseases of the crop in question. The possible production is obtained by dividing the actual production by 100% minus the total percentage of loss from all diseases of the crop. Thus:

$$\text{Possible production} = \frac{\text{Actual production}}{100\% - \%\ \text{loss from all diseases of the crop.}}$$

The estimated loss from a given disease, then, is obtained by multiplying the estimated possible crop production by the estimated percentage loss from the disease, thus:

$$\text{Estimated crop loss} = \frac{\text{Actual production.}}{100\% - \%\ \text{loss from all diseases.}} \times \%\ \text{individual disease loss.}$$

For example, suppose the actual production of a 10-acre apple orchard to be 5,000 bushels, and it is estimated the loss for all diseases is 15%. Then—

$$\frac{5{,}000}{100\% - 15\%} = 5{,}882 \text{ bushels} = \text{possible production.}$$

To estimate the loss from a given disease: suppose in this orchard the loss from black-spot were 5%. Now, 5,000 bushels represents 85%; therefore—

$$1\% \text{ is } \frac{5{,}000}{85} \text{ bushels;}$$

$$\text{and } 5\% = \frac{5{,}000}{85} \times 5 = 294 \text{ bushels} = \text{estimated loss from black-spot.}$$

These figures are based on reports submitted by plant pathologists throughout the United States, so that all conditions of climate, humidity, etc., are covered. If anything, they err on the conservative side, especially when applied to New Zealand conditions, for, with the exception of the arid regions of Central Otago proper, most of the diseases discussed here are widespread throughout, differing in this respect from the United States, where in so many localities dry conditions prevail.

UNITED STATES FIGURES OF CROP LOSSES.

PEACHES.

Year.	Total yield in bushels.	Percentage losses due to		
		Leaf-curl.	Brown-rot.	*All diseases.
1919	51,340,000	2.21	7.71	12.04
1920	43,697,000	3.00	11.40	19.40
1921	32,733,000	0.60	7.20	15.30

APPLES.

Year.	Total yield in bushels.	Percentage losses due to				
		Bitter-rot.	Black-rot.	Fire-blight.	Black-spot.	*All diseases.
1919	147,457,000	1.21	1.36	0.69	3.93	11.37
1920	240,442,000	1.00	1.30	1.20	6.00	16.50
1921	96,881,000	1.20	0.50	1.00	5.70	11.30

* Includes also diseases not mentioned in table.

These percentage figures, when applied to New Zealand crops, give in a startling manner some idea as to the losses caused by plant diseases. For example, if we take from the preceding table the minimum and maximum percentage losses due to certain orchard diseases of the peach and the apple, and apply them to the 1922-23 crop returns for the Dominion, we get the following results:—

TABLE OF PROBABLE LOSS FROM PLANT DISEASES, Season 1922-23.

Variety.	Yield in bushels.	Average price per bushel.	Total value of crop.	Percentage loss.	Monetary loss.
Apples	1,469,242	5/-	£367,310	Min. 11.30 Max. 16.50	£41,505 £60,605
Peaches	132,201	6/9	£44,617	Min. 12.04 Max. 19.40	£5,371 £8,655

For literature references, see bibliography, p. 349, numbers *12, 14, 16, 249, 250, 306.*

CHAPTER VII.

REMEDIAL TREATMENT.

Plant Protection; Dusting and Dusts; Formulæ; Insecticides; Chemistry of Insecticides; Arsenate of Lead; Black-leaf 40; Kerosene Emulsion; Red-oil.

Methods for the control of fruit-tree diseases may be grouped as follows:—

a. Plant protection;
b. Orchard sanitation;
c. Propagation of resistant varieties.

Of these the first two are widely followed, but the third has not as yet reached beyond the experimental stage.

a. PLANT PROTECTION.

To protect plants against insect and fungous attack, and to destroy ectoparasites, certain chemical compounds toxic to the parasite yet non-injurious to the host, are widely employed. These may be applied in either liquid or powder form, and when used against insects are termed insecticides, against fungi are termed fungicides, or against both, are termed dual sprays or dual dusts, according to whether the substance be applied in liquid or powder form. The process of applying substances in liquid form is termed spraying, that of applying them in powder form, dusting. A third method of combating certain insects is on occasion used in citrus-growing regions; this consists of covering the trees with a gas-proof cover, then generating certain gases which asphyxiate the insects without detriment to the tree. As this practice is not followed in New Zealand, it will not be further discussed.

Fungicides and insecticides, whether applied in liquid or powder form, to fulfil all requirements must be—

1. Capable of destroying the parasite,
2. Non-injurious to the host,
3. Easy to apply,
4. Easy to prepare,
5. Reasonable in cost.

DUSTS AND DUSTING.

Dusting for the control of fungi and insects has not been practised commercially in New Zealand, so that no data can be given as to its utility; but from the results obtained by experimentalists in North America, it would appear as if dusting will shortly be the principal method adopted for the control of fungous diseases and insect pests. The principal defects of the system at present appear to be in the apparatus used, and the fact that the best of the dust materials experimented with do not possess the same fungicidal value as the best sprays, such as bordeaux mixture, and in the case of insect pests, no efficient contact dust is in use.

The advantages of dusting may be summarised as under:—

1. Initial cost of the apparatus is about half that of spray apparatus.
2. The upkeep of the apparatus is much less.
3. It takes less than half the time to dust an orchard that it does to spray it.
4. The apparatus weighs much less, consequently it may be used on land that would be impassable to the spray outfit.
5. No water is required—a big factor in its favour, especially where water is scarce.
6. Takes less time to fill the apparatus.
7. Dusting may be performed at any time, regardless as to whether the trees are wet or dry.
8. There is little or no deterioration of the dust in storage.
9. Dusting causes little inconvenience in handling.

American experiments have shown that when sprays are applied up to the time of blossoming, dusting with sulphur-arsenate of lead powder will readily hold in check thereafter black-spot, leaf-curl, brown-rot, codlin-moth and other chewing insects. In fact, it is as good as, if not better than, the dual spray, lime-sulphur + arsenate of lead.

One of the great advantages of the method is the speed with which the orchard can be covered, partly owing to the light draught of the apparatus, partly to the speed with which the apparatus may be recharged, and largely because no stoppages are required, for the apparatus may be driven down one row and up the next. Although dust materials cost more than sprays, the speed with which the operation may be carried out more than counter-balances this initial extra cost by the time saved. It must be stated that the process has not yet passed the experimental stage, but the results obtained certainly justify investigation under New Zealand conditions.

Numerous commercial dusts are on the market, but for the grower who is desirous of making his own, the following formulæ are given:—

Sulphur-arsenate of lead powder, 90-10 formula.

Finely ground sulphur ..	90 parts
Arsenate of lead powder ..	10 parts

It is necessary that the materials be so finely ground as to pass through a sieve having 200 meshes to the inch. This formula may be used as a dual dust for the control of codlin-moth and black-spot; or on peaches for brown-rot and caterpillar. It is advisable to spray as recommended (under spray schedules, p. 85) until after the petals have fallen, when the dust may be used in place of the lime-sulphur sprays, if applied at the same times. It is claimed that this dust tends to prevent transit or store infection from brown-rot.

A second formula is Sanders' *(273)*—

Bordeaux dust, formula 15-8-77.

Dehydrated copper sulphate	15 parts
Calcium arsenate	8 parts
Dehydrated lime	77 parts

It is claimed that this is equal to bordeaux mixture for the control of black-spot. It is necessary to warn the orchardist that any of these substances should first be experimented with in a small way, for where too much is applied to a tree severe leaf-scorch and fruit-cracking may result.

SPRAYS.

These are various chemical substances applied in solution or in suspension, water being largely the vehicle of application, for when it has evaporated the chemical substances are left on the fruit or leaf in the form of minute particles. The finer the spray, the finer will be the particles deposited, as will be seen when spraying is considered. Both insecticides and fungicides are applied in this manner, and as they differ considerably in their chemical nature and action, each group will be considered separately.

* INSECTICIDES.

In order to understand the action of insecticides, it is necessary to consider the structure of and methods of feeding among insects. Take any caterpillar for example; the body is covered and protected by a more or less tough skin, each side being perforated at intervals by a row of small openings or stigmata (the breathing pores), each of which leads into a tube or trachea within the body. These air tubes or tracheae unite to form the breathing system and branch in all directions, distributing air to all parts of the body. The mouth, situated on the under side of the head, is surrounded by a set of jaws, by means of which the plant tissues are shred before being swallowed and passed on for digestion. The "leech" and the grubs of beetles are built on much the same plan. While the adult of the caterpillar—a moth—differs in its method of feeding on account of the mouth parts being in the form of a long and tubular proboscis, and is thus incapable of shredding its food like the caterpillar, the adult beetle feeds in much the same way as its grub.

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* Compiled from data supplied by David Miller, Entomologist, Biological Laboratory, Department of Agriculture, Wellington.

Though insects as a whole are protected and breathe in this manner, there is, apart from the caterpillar type, a large group—the aphids, scale-insects and plant-bugs—which do not shred their food, but live on the internal juices of plants, their mouth parts being modified in the form of a delicate needle-like structure for puncturing the tissues in order to reach their food—the cell sap.

In orchard practice, therefore, insects may be grouped as under:—

1. *Mandibulate,* or those such as caterpillars and beetles, which tear or shred their food by means of jaws;
2. *Sap-feeders,* such as scale-insects or aphids, incapable of taking solid food, which feed on the plant sap by puncturing the outer tissues with their needle-like probosces.

According to this grouping, insecticides are divided into—

a. *Stomach poisons.*
b. *Contact insecticides.*

a. Stomach poisons.—These insecticides are applied obviously to control mandibulate insects, the poison gaining access with the food directly to the digestive system. They would be ineffective against the sap-feeders, since the food of such is protected from the spray by the epidermis of the host plant. The principal stomach poison in use is arsenate of lead. This spray is most effective when applied against the *young* insects (caterpillars and grubs), since the older the insect (particularly in the adult stage, if a beetle), the more difficult to poison.

b. Contact insecticides.—These are effective against both groups of insects, since they act directly on the body or through the breathing system, or even at times as a stomach poison; but they are used mainly against sap-feeders. Contact insecticides are either—

Corrosives, acting directly on the insect body; or
Fumigants, acting through the breathing system.

Those used at present in commercial orchards are—

Lime-sulphur, a corrosive, a fumigant (to a limited extent), and sometimes a stomach poison.

Red-oil, a fumigant, blocking the stigmata, and inducing asphyxiation.

Black-leaf 40, a fumigant, acting upon the breathing system, and possibly as an irritant stomachic poison.

Kerosene emulsion, which has the same action as red-oil.

Hydrocyanic acid gas } Both used in fumigating, a prac-
Carbon disulphide } tice not adopted in New Zealand.

Of these, the first three are widely used in combination, forming dual sprays, which are discussed at greater length on p. 79. Red-oil is perhaps the most efficient to use against scales and woolly-aphis, but is a costly spray to apply alone, whereas lime-sulphur, applied at the same time (dormant season), although not as efficient an insecticide, serves as a dual spray, destroying both insects and fungi.

CHEMISTRY OF INSECTICIDES.

1. *Arsenate of Lead.*—This compound has now completely superseded paris green, at one time so widely used in the control of codlin-moth and "leech," the principal reason being that paris green (aceto-arsenite of copper) was apt to scorch the foliage and cause cracking and premature fall of the fruit. Moreover, it cannot be used in combination with lime-sulphur. Arsenate of lead is not of constant composition, for analyses of different samples from different manufacturers have shown the proportions to vary considerably, even in different samples from the same manufacturer *(85)*.

The formulæ recommended by Pickering *(85)* for the manufacture of arsenate of lead are as under:—

Lead acetate	1.9 parts
Sodium arsenate (cryst.) ..	1.0 part

or

Lead acetate	3.5 parts
Sodium arsenate (anhyd.)	1.0 part

This produces the compound $Pb_3(AsO_4)_2$, together with a small quantity of free acetic acid. The second formula is—

Lead nitrate	1.25 parts
Sodium arsenate (cryst.)	1.0 part

or

Lead nitrate	2.5 parts
Sodium arsenate (anhyd.)	1.0 part

This produces the compound $Pb_2H_2(AsO_4)_2$, though this is apparently not constant in composition.

A weak solution of sodium arsenate is slowly added to (or *vice versa*) a strong solution of the lead salt (either acetate or nitrate) until cloudiness ceases.

Arsenate of lead may be used with bordeaux mixture or lime-sulphur without any increased danger of leaf-scorch. When used alone or in combination, 1½ lbs. of powder or 3 lbs. of paste to 100 gallons of water is the strength recommended.

2. Black-leaf 40.—This is a commercial compound, the effective ingredient of which is nicotine sulphate. It is one of the most efficient contact insecticides known, for it quickly destroys all soft-bodied insects, such as caterpillars, aphids and young scales. It is used at the strength of 1 part in 800 parts of water, and may be applied alone or in combination with lime-sulphur at any time of the year, for at this strength it has no detrimental effect on the foliage.

3. Kerosene emulsion.—Kerosene is one of a series of paraffins obtained by the distillation of natural oils obtained from the oil-fields of North America, Borneo and elsewhere. Kerosene emulsion came into vogue as an insecticide especially for the control of scales and woolly-aphis, but has been displaced by the use of emulsified red-oil. The formula for the manufacture of this emulsion is:

Soap (or soft soap)	8 ozs.
Kerosene (150°)	2 gallons
Water	1 gallon

Heat the water, and to this add the soap cut into shreds, and stir until dissolved; remove from the fire, and immediately add the kerosene; agitate until completely emulsified, either pouring several times from one vessel to the other, or preferably by passing through a small spray pump. Use in the dormant season at the strength of 1 part to 6 parts of water; or during the growing season at a strength of 1 part to 15 parts of water.

Lime-sulphur.—As this is more properly a fungicide, it is dealt with under that section, p. 74.

Red-oil.—To-day the brands of red-oil on the market are paraffins of a heavier type than kerosene (although obtained in a similar manner from natural oils), to which has been added an emulsifier. Thus there is little need for the emulsification of such commercial preparations. For those orchardists who desire to emulsify their own oils, the following formula is given:—

Oil	1 gallon
Soap	1 pound
Water	15 gallons

Prepare as for kerosene emulsion. For use whilst the trees are dormant, spray at full strength; for citrus trees, it may be used when diluted with 4 gallons of water to each gallon of the solution. Commercial red-oils should be used according to the strengths specified by the manufacturers; if these are not available, use in the dormant season at a strength of 1 part of the oil to 10-12 parts of water. On citrus trees use at a strength of 1-60.

For literature references, see bibliography, p. 349, numbers *35, 38, 45, 85, 86, 132, 209, 237, 246, 251, 252, 273, 298, 336.*

CHAPTER VIII.

REMEDIAL TREATMENT.

(Continued.)

Fungicides; Chemistry of Fungicides; Precipitated Sulphur; Bordeaux Mixture; Method of Preparing Bordeaux Mixture; Bordeaux Paste; Burgundy Mixture; Lime-sulphur; Home-made Lime-sulphur; Tables of Dilutions of Lime-sulphur; Self-boiled Lime-sulphur; Bordeaux-oil Emulsion; Iron Sulphide Solution; Spreaders or Stickers.

FUNGICIDES.

The fungicides in use to-day among commercial growers throughout the Dominion are:—

Bordeaux mixture.
Burgundy mixture.
Lime-sulphur.
Precipitated sulphur.

In addition to these, are given several of the more recent sprays which have proved satisfactory abroad. Fungicides are applied with a view to destroying fungi and fungous spores present on the host, and with the object of coating the developing leaves and fruits with a protective covering. The latter is the principal object achieved with all sprays applied during the growing season; for with most diseases sprays may prevent them from becoming established, but will do little in the way of destroying those already established (other than ectoparasites). Theoretically, the practice of spraying consists in applying, in solution or in suspension (in water) certain substances which in solution are toxic to the parasite, yet innocuous to the host. Naturally, as both are plants, this means that the difference between the killing effect of the solution on the fungus and its non-injurious effect upon the host is one of dilution only, a solution of known strength, toxic to the fungus, but harmless to the leaves and fruit of the tree, being applied. When stronger solutions are used, detriment to the leaves and fruit follows, so that strong solutions are applied only when few or no leaves and fruits are present.

The solution is applied, and coats the surface of the leaf or fruit; the water evaporates, and the materials are precipitated. If the materials are in solution, and the spray applied as a fine mist, then the fungicide naturally is distributed over the surface as exceedingly minute particles. If the materials are in suspension, and a misty spray applied, the particles would be slightly larger, provided they were very finely comminuted ere they were placed in the tank. If the materials are in a coarse condition when placed in the tank, or if a coarse nozzle is used and the spray thrown on to the leaves and fruit in large drops, or if the spray is not properly made, then the particles may be deposited in large and irregular groups, at widespread intervals over the surface, where they may adhere or fall away, according to their size. Most sprays, when applied, are partially or wholly insoluble, according to their nature. When dried as a film in scattered particles over the surface of the host, they also are insoluble, or at least inert. So that ere they are able to function, sufficient of the fungicide, in a soluble form, must be released. If weather conditions are exceptionally dry, and the nights warm, the fungicide may persist for weeks in an insoluble condition; such a case is very unusual, however. This does not apply to certain sulphur compounds. Fortunately, under such abnormal conditions, no infection from fungous spores could occur, for it will be remembered that these spores germinate only in the presence of moisture, and, with the majority, only when actually surrounded by a film of water. In most localities moisture is deposited at night as a thin film spread over the surface of the leaf or fruit. This carries with it in solution certain gases or other substances, which act upon and render soluble, and consequently active, certain quantities of the particles of spray deposited thereon. Naturally, as the chemical composition of the different sprays differs, so will the action of these gases in solution differ.

From this brief discussion, it may be realised why different formulæ are used for different seasons. These differences are partly to avoid spray injury to the host; partly to vary the immediate solubility of the spray used.

CHEMISTRY OF FUNGICIDES.

In order to be clear on many points in connection with their use, it is necessary to possess some knowledge of the chemical composition (where known) and manufacture of fungicides.

1. *Precipitated sulphur* ("atomic sulphur"; "sulphur atoms").—The success in the use of this substance depends largely on the degree of fineness attained in its manufacture. To obtain sulphur in such a fine state of division necessitates its preparation by chemical precipitation, a process which is somewhat costly, hence the reason for the high price of such preparations.

When alkaline polysulphides are treated with hydrochloric acid in aqueous solution, hydrogen sulphide is given off, and at the same time a precipitate of almost white sulphur is produced. This, when dried, appears in the form of an impalpable powder which, in the pure form, or adulterated with inert substances, is sold as atomic sulphur or sulphur atoms. Precipitated sulphur may be applied at a strength of 8-10 lbs. in 100 gals. water, and is especially useful against ectoparasites, such as powdery-mildew, for it may be applied during the growing season without detriment to the host. It would appear that its principal action lies in the emission of certain vapours, the nature of which is unknown. Neither sulphurous acid nor sulphuretted hydrogen (H_2S) are produced *(51)*. The more finely divided it is, the greater will be its effectiveness. It is most effective during warm and dry weather, and as water does not play any part in its action, it is the most suitable fungicide to use against powdery-mildew, for this fungus thrives best in a dry and warm atmosphere. These vapours affect only fungi exposed to their action, hence its efficacy against powdery-mildew, and its non-effectiveness against most endoparasites. It may be used in combination with lime-sulphur and arsenate of lead.

2. Bordeaux mixture.—Discovered in 1882 by accident, this has proved to be the most efficient fungicide known. Unfortunately, its effect upon young fruit and leaves of stone-fruits and apples is such that it cannot be used while the foliage is on the tree without grave risk of causing defoliation and russeting. It may be used at this period on pears and citrus-fruits, provided the solution used is of a suitable strength.

Bordeaux mixture consists of a mixture of copper sulphate (bluestone), calcic oxide (burnt lime) and water. The relative proportions of each and the methods to be used in mixing, in order to obtain the best results, are still largely a matter of dispute. The fungicidal action appears to be due wholly to the small amounts of soluble copper which are liberated during weathering on the surface to which it is applied. This soluble copper has a destructive action on all living plant tissues, whether host or fungus. The ideal mixture would maintain for the maximum time just sufficient copper in solution in the atmospheric moisture on the plant to kill germinating fungous spores, while never liberating sufficient to prove harmful to the plant tissues.

The chemistry and physics of the reactions which take place when solutions of copper sulphate and lime are mixed have been investigated in the laboratory by many workers, notably Pickering *(36; 240)* and Butler *(74)*, but it is at least doubtful if the conclusions drawn therefrom can be applied to spraying practice. The only reliable guide to the proportions of the various ingredients to be used and to the methods of mixing and application is by actual experiments in the orchard—experiments to find the mixture which will give the maximum control of the fungus with the minimum damage to the leaves and fruit. The formulæ recommended here are all based on experimental work of this character.

Method of making bordeaux mixture.—Stock solutions of copper sulphate and lime are first made up in special barrels.

The stock solution of copper sulphate should be made up so as to contain a definite and convenient weight of bluestone in each gallon of the stock solution. For instance, if 40 pounds of bluestone are dissolved in 20 gallons of water, then each gallon of the resultant solution will contain 2 pounds of bluestone, so that in making a 5-4-50 bordeaux, in a 100-gallon spray tank, five gallons of the stock solution will give the requisite amount of copper sulphate. The bluestone is dissolved by suspending overnight in a scrim or cheese-cloth bag, supported just below the surface of the water in the barrel, or it may be made more rapidly by using hot water. The solution will remain good indefinitely (though, of course, gradually concentrating by evaporation) so long as it comes in contact only with wood.

The stock solution of lime should be prepared from fresh, well-burnt lime, containing at least 90% calcic oxide. As in the case of the copper sulphate stock solution, a definite weight should be taken, so as to give at the convenient dilution a stock solution containing a simple unit quantity of lime per gallon. The usual quantity is one pound per gallon, requiring for a 40-gallon barrel of stock solution 40 pounds of lime. The lime may be slaked with either hot or cold water—the former having some advantages. Sufficient water should be first added to just cover the dry lime; when this is absorbed, a further small quantity should be added and left until absorbed, continuing the process until no more water is taken up and the whole becomes pasty, when the balance of the water may be added to make up the required volume. This stock solution will keep well for a considerable time; it should be well stirred before dipping out the quantity required for each mix. Having prepared the two stock solutions, the next step is to make from them bordeaux mixture, and the procedure adopted appears to affect materially the spray efficiency of the result. All investigators of this matter are agreed that to mix the two strong solutions together, and then to dilute with water to spray strength, is fatal to the efficiency of the mixture. There is less agreement on the other possible methods, but it is generally recommended that the required quantity of one of the ingredients should be added to the full quantity of water to make up to spraying strength—the other ingredient being then added straight from the stock barrel. Pickering *(38)* strongly advocates that the lime should first be diluted and the stock copper solution subsequently added, while

Butler *(74)* recommends the converse procedure. In any case, the mixture should be kept well stirred during spraying, and should be used within twelve hours.

The lime in the foregoing description of the stock solution is in the form of "milk of lime"—that is, a solution of lime in water ($Ca(OH)_2$), with a further and much larger quantity of lime held in the form of small solid particles in suspension. If these solid particles are allowed to settle, the clear liquid remaining is "lime-water," a true solution of lime, which at ordinary temperatures will contain about one part of lime in 800. Lime-water is sometimes used instead of milk of lime—as in the "Woburn wash"—but the weak concentrations available by this method very much restrict its usefulness in practice.

The two formulæ recommended are:—

Copper sulphate ..	5 lbs.	Winter solution.
Quick-lime ..	4 lbs.	
Water ..	50 gals.	

and

Copper sulphate ..	3 lbs.	Summer solution.
Quick-lime ..	4 lbs.	
Water ..	50 gals.	

Bordeaux paste.—This compound frequently is used for painting over wounds that have been caused through the removal of diseased bark from cankered areas. It is commonly recommended for the treatment of wounds formed as the result of treating trees infected with bark-blotch or cellar-rot, but the author is of the opinion that more satisfactory results will be obtained by the use of the solution used for the treatment of fire-blight cankers (p. 36). For those desirous of using bordeaux paste, the following formula is given:—

Copper sulphate	1 lb.
Quick-lime	2 lbs.
Water	1.5 gals.

Dissolve the copper sulphate in half the quantity of water, and slake the lime with the remainder. When slaking has ceased, stir the lime mixture into a stiff paste, at the same time slowly adding the copper sulphate solution. This solution may be considered more of the nature of a paint than a paste, for it has the consistency of treacle, and, indeed, in the literature dealing with these compounds we frequently find references to "bordeaux paste" and "bordeaux paint." They are in reality the same thing, differing merely in the quantity of water used, or in the proportions of lime to copper sulphate. The advantage of the above formula is that it gives a compound which is readily applied with a brush, yet tenacious enough to withstand weathering. If too thick, the compound must be applied with a spatula, a costly and tedious operation.

3. Burgundy mixture.—This consists of a mixture of copper sulphate, sodium carbonate (washing soda) and water. Like bordeaux, its fungicidal action results from the slow liberation of soluble copper under the influence of atmospheric moisture. The relative efficiency of burgundy and bordeaux mixtures is still a matter of dispute, but there is no doubt that in practice the former is easier to prepare and pleasanter to handle, especially where small quantities only of the spray are required. Practically all the matter given above under bordeaux mixture will apply equally well to burgundy mixture, substituting soda for lime, though, of course, the actual formulæ will not be identical. Burgundy is recommended only as a spray to be applied at bud movement; at this stage the following formula may be used:—

Copper sulphate	4 lbs.
Washing soda	5 lbs.
Water	50 gals.

When made according to this formula, the spray is more adhesive than bordeaux. The orchardist is warned against using this in a weaker form for a summer spray, for it has frequently caused severe injury to foliage. It must *not* be used in combination with arsenate of lead.

4. Lime-sulphur.—Following American practice, lime-sulphur sprays have been widely used in New Zealand in recent years. Their main value lies in the fact that they act as controllants both of insects and fungi, and that when used in the proper manner they have no scorching effect on leaves or fruit. When quick-lime and sulphur are heated together in water, a variety of compounds are formed, the relative proportion of each varying with the methods used. Horton and Salmon *(165, bis.)* have shown that the fungicidal action of lime-sulphur solution is due solely to one group of these compounds, namely, the calcium polysulphides. Thus the value of a lime-sulphur solution will vary with the proportion present of this group as compared with the other non-fungicidal compounds present. Unfortunately, there is no readily available method whereby this can be ascertained, for neither the total percentage of sulphur nor the specific gravity of the solution affords any reliable index to its relative composition. For practical purposes, the main point in a lime-sulphur solution is constancy of composition, so that the observed results with one application may be applied with confidence to those following. In general, good commercial brands of concentrated lime-sulphur are more uniform in composition than home-made, though some of the most careful growers find that they have fewer unpleasant surprises by making their own. Commercial lime-sulphur is usually a more concentrated solution than the home-made article, the specific gravity or degrees Beaume generally being guaranteed with the sale. However, it is always well to test with a hydrometer each batch of solution before use, the requisite dilution then being obtained from the dilution table on p. 76.

The following strengths are recommended, using lime-sulphur, 33° Beaume:—

POME-FRUITS	Dormant season	Lime-sulphur Water	10 gals. 100 gals.	= 1-10
	Open cluster	Lime-sulphur Water	3⅓ gals. 100 gals.	= 1-30
	Trees in leaf	Lime-sulphur Water	1 to ⅚ gal. 100 gals.	= 1-100 to 1-120
STONE-FRUITS	Bud movement	Lime-sulphur Water	6⅔ gals. 100 gals.	= 1-15
	Trees in leaf	Lime-sulphur Water	⅚ gal. 100 gals.	= 1-120

Home-made lime-sulphur.—For those desirous of making their own lime-sulphur the following directions are given:—

Procure good quality quick-lime, as free from impurities as possible, and sulphur which should be very finely divided, free from impurities, and which should preferably be run through a fine sieve ere it is used. Procure an *iron* (not a copper) boiler capable of holding 50-60 or more gallons, a hydrometer with a scale reading from 1.000 to 1.330 specific gravity, or one reading from 0° to 36° Beaume, a wooden paddle with a long handle for agitating, and a barrel in which to store the prepared solution.

The quantities of materials required are:—

Unslaked lime (90% CaO) . .	25 lbs.
(or slaked lime)	(34 lbs.)
Sulphur	50 lbs.
Water	30 gals. (approx.)

Place about five gallons of water in the boiler, light the fire, and add the lime. When slaking is vigorous, add the sulphur, preferably mixed into a paste, and stir thoroughly, adding just enough water to make a thin paste of the whole. When slaking ceases, add the remainder of the water, and boil *vigorously* for one hour.

stirring all the time, and being careful to break up all lumps. The fumes cause the eyes to smart and water, but this may be avoided by the use of motor-goggles.

At the end of the hour draw the fire and strain the solution through a fine galvanised iron strainer into the container. When cool, test with the hydrometer. It will be found that the reading is in the vicinity of 1.22-1.24 sp. g., or 26°-28.5° Beaume.

As the formulæ recommended in this book are based on the 33° Beaume standard, it is obvious that less water will be required for the home-made article. See below.

TABLE OF DILUTIONS OF LIME-SULPHUR SOLUTION TO MAKE UP TO REQUIRED SPRAYING STRENGTH.

Degrees Beaume.	Specific Gravity.	Volumes of water to be added to one volume of the solution. Spray strengths.				
		1-10	1-15	1-30	1-100	1-120
20	1.160	6.1	9.1	18.2	60.6	72.7
21	1.169	6.4	9.5	19.1	63.6	76.4
22	1.179	6.7	10.0	20.0	66.7	80.0
23	1.188	7.0	10.5	20.9	69.7	83.6
24	1.198	7.3	10.9	21.8	72.7	87.3
25	1.208	7.6	11.4	22.7	75.8	90.9
26	1.218	7.9	11.8	23.6	78.8	94.5
27	1.229	8.2	12.3	24.5	81.8	98.2
28	1.239	8.5	12.7	25.5	84.8	101.8
29	1.250	8.8	13.2	26.4	87.9	105.5
30	1.261	9.1	13.6	27.3	90.9	109.1
31	1.272	9.4	14.1	28.2	93.9	112.7
32	1.283	9.7	14.5	29.1	97.0	116.4
33	1.295	10.0	15.0	30.0	100.0	120.0

OTHER SPRAYS.

Self-boiled lime-sulphur.—This is quite an efficient spray for the control of brown-rot, peach-scab and leaf-rust, and has little, if any, scorching effect upon the foliage. The formula recommended is:—

Quick-lime	8 lbs.
Sulphur	8 lbs.
Water	50 gals.

The lime used should be of good quality, and the sulphur free from all lumps. Place the lime in a wooden tub, and add one or two gallons of water, preferably hot water, as then the risk of "drowning" the lime is lessened. When slaking becomes vigorous, add the sulphur, and stir constantly, adding more water as required to form a thick paste. When slaking ceases, cool the solution by adding three or four gallons of cold water, being careful to do this before any reddish colour appears. The mixture may then be poured through a strainer into the remainder of the water in the spray tank, and the agitator kept going during this operation.

No heating is required for the preparation of this compound, the heat generated during the slaking of the lime being all that is required. One defect of this spray is that it settles rapidly, so constant agitation is necessary; but this is not a serious defect with the modern power plant. Arsenate of lead may be safely added to this solution.

Bordeaux-oil emulsion (329; 336).—This is a dual spray which possesses all the fungicidal properties of bordeaux mixture, with the added quality of being an efficient insecticide. It is being used widely in the citrus-groves of Florida, and should be equally successful in the citrus areas of New Zealand. Its use in this connection would obviate the necessity for using a separate red-oil spray (1-60) for the control of scales. Further, the presence of the emulsion tends to spread the spray in a more efficient manner, acting in this connection like a commercial spreader.

The emulsion principally used in Florida is made after Yothers' boiled oil formula *(336)*, the formula of which is:—

Paraffin oil (sp. g. 0.863) ..	2 gals
Water	1 gal.
Caustic-potash fish-oil soap ..	2 lbs.

Place oil, water and soap in a bucket and bring to the boil. Remove from the fire, and, while still hot, run several times through a hand pump until emulsified. Fill the spray-tank with bordeaux 3-4-50, and whilst running the agitator add 3 gallons of the emulsion (that is, provided the spray tank holds 200 gallons; if not, add a proportionate amount); or take 3⅓ gallons of emulsified red-oil, and emulsify with a small quantity of water, and add to the tank. The main point to be borne in mind is that the emulsion is to be added to the bordeaux solution slowly and only when freshly-made bordeaux is being agitated in the tank. This produces a dual spray, in which there is 1% of oil (approx. 1-60).

Iron-sulphide solution.—This is made by adding sulphate of iron ($FeSO_4$) to a solution of lime-sulphur. As a result, calcium sulphate and iron sulphide are produced, and a quantity of sulphur is precipitated in an extremely fine state of division. It is probable that only the sulphur in this solution possesses any fungicidal properties. Such being the case, the grower is advised to use precipitated sulphur, which may be procured commercially under the names of atomic-sulphur or sulphur-atoms, thus obviating the necessity of undertaking the preparation of iron-sulphide solution, a process which is tedious, slow and costly.

SPREADERS OR STICKERS.

For many years attempts have been made by the use of various substances to improve the adhesive properties of the sprays used. For this purpose, oils, resins, soaps, glue, milk, molasses and other substances have been used, but calcium caseinate—a manufactured bye-product from the dairying industry—is the only one which has come into general use. The addition of calcium caseinate, at the rate of one pound per hundred gallons of spray, undoubtedly increases the wetting and penetrating properties of the solution. The film of spray left on leaf or fruit when this spreader is used, dries out much more evenly and leaves the dissolved or suspended particles more equally distributed over the surface. It is claimed for it that the spray film it leaves stretches with the developing fruit, so that at no time is any part of the surface uncovered to the attacks of insects and fungi. Especially with arsenate of lead is this spreader valuable, since it helps to prevent settling in the spray-tank. For the combined lime-sulphur + arsenate of lead summer sprays its use can safely be recommended. With bordeaux, the results are not so satisfactory—the bordeaux-oil emulsion on p. 77 will probably be found to give better results.

For literature references, see bibliography, p. 349, numbers *36, 38, 51, 74, 75, 77, 165 bis, 240, 296, 303, 329, 336.*

CHAPTER IX.

REMEDIAL TREATMENT.

(Continued.)

Dual and Combination Sprays; Compatibility Tables; Spraying; Blossom Stages; Spray Apparatus; Sprayers; Spray Schedules; Spray Costing; Table of Spray Costs; Superstitions.

Dual sprays are sprays which function both as insecticides and fungicides; combination sprays consist of two or more individual insecticides or fungicides, or both, combined so as to minimise the labour and the water required for application.

DUAL AND COMBINATION SPRAYS.

Little need be written with reference to these, save to indicate which sprays may be mixed with safety and those dangerous to combine. The objectives aimed at in mixing two or more sprays together vary according to the nature of the sprays and the purpose for which they are to be used. For little would be gained in combining (say) two fungicides, the properties of each being equal, unless by chemical action a substance were formed possessing better fungicidal properties than either. Such a combination would be useful in certain cases where two or more fungi of different habit (requiring different methods of treatment) were present on a tree.

For example, the combination of precipitated sulphur and lime-sulphur is advisable where black-spot and powdery-mildew are present, for precipitated sulphur is the most efficient sulphur-containing fungicide for mildew, yet is of little use as a controllant of black-spot, whereas lime-sulphur is of little value as a controllant of the mildew, but of some use against black-spot. Thus such a combination would be used only when the control of different types of fungi—ectoparasites and endoparasites—was being attempted. Similarly with insecticides, where mandibulate and sap-feeding insects were present, the spray used would be one capable of destroying both types, or, as is more frequently the case, two insecticides would be used—one a stomach poison, the other a corrosive or fumigant. Further, as the cost of applying the spray is greater than the cost of the material (at summer strength), the orchardist may, to reduce spraying costs, attempt the control of mandibulate and sap-feeding insects, simultaneously with the control of fungi, either ectoparasitic or endoparasitic fungi, or both, with a single application of a combination spray.

The time of the season is another factor governing the use of combination sprays. In general, it may be stated that the sprays used in the dormant season are bordeaux, lime-sulphur, and red-oil; those used up to the pink stage, lime-sulphur and bordeaux; those used through the growing season, lime-sulphur, precipitated sulphur, black-leaf 40, and arsenate of lead.

The cost of each spray is a third factor, compelling consideration of dual or combination sprays. For example, the most efficient method of combating both insects and fungi on apple trees would be an application of red-oil in the dormant season; bordeaux at green-tip; lime-sulphur at pre-pink; lime-sulphur + arsenate of lead at petal-fall; followed up with several applications of various kinds throughout the growing season. This, in most cases, would prove too costly a procedure, so that growers modify this somewhat by using a dual spray (lime-sulphur) at green-tip, which, although not as efficient an insecticide as red-oil, nor a fungicide as bordeaux, yet in certain districts is capable of holding both fungi and insects in check.

It is impossible to lay down a general schedule for all districts, so that the orchardist must apply those sprays which will prove the most efficient for combating diseases or pests most troublesome in his locality, and which will give the most efficient results with the minimum of outlay. A table of the probable cost, based on actual costs, of each application is given on p. 91; from this the grower should be able to calculate the cost of his season's spray programme.

The following sprays may be combined without detriment to the properties of either, and without increasing their harmful effect upon the host:—

Arsenate of lead	Precipitated sulphur Lime-sulphur Black-leaf 40 Bordeaux mixture
Burgundy mixture	Black-leaf 40
Black-leaf 40	Precipitated sulphur Lime-sulphur Arsenate of lead Bordeaux mixture
Bordeaux mixture	Red-oil Black-leaf 40 Arsenate of lead
Lime-sulphur	Precipitated sulphur Black-leaf 40 Arsenate of lead
Precipitated sulphur	Lime-sulphur Black-leaf 40 Arsenate of lead
Red-oil	Bordeaux (3–4–50)

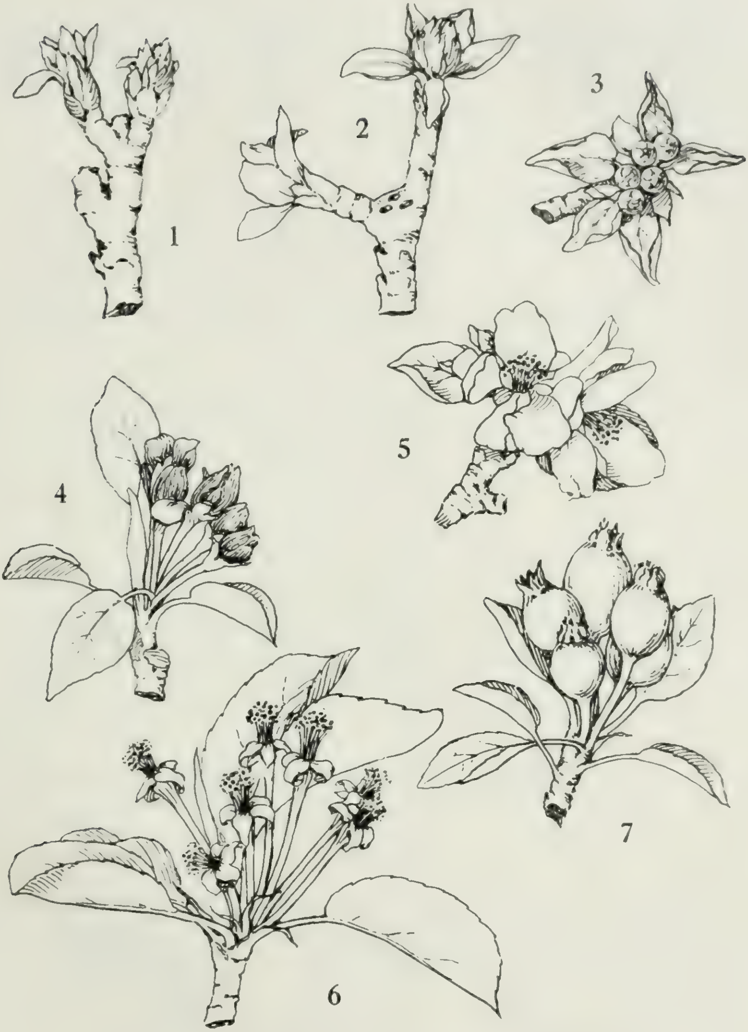

Fig. 21. STAGES OF APPLE-BLOSSOM DEVELOPMENT.
1. Green-tip; 2. tight cluster; 3. open cluster; 4. pink; 5. full bloom; 6. petal fall; 7. calyx closed.

Drawing by N. J. Adamson.

SPRAYING.

All sprays should be applied as nearly as possible at the periods stipulated in the schedules. An explanation of the terms used in the schedules is given below, together with an accompanying series of drawings, illustrating the more important of these stages:—

1. *Dormant season*	This implies any period between leaf fall and bud movement.
2. *Bud movement*	When the buds begin to swell, and the protecting scales to fall, but before any leaves appear.
3. *Green tip*	When the first leaves are beginning to show, but before any blossom buds appear (Fig. 21, 1).
4. *Tight cluster*	When the blossom buds are visible, but still closely compacted together (Fig. 21, 2).
5. *Open cluster*	When the buds are more exposed, and partially separated from one another (Fig. 21, 3).
6. *Pink*	When the petals are visible, but before the blossoms have expanded (Fig. 21, 4).
7. *Full bloom*	When the majority of the petals are widely expanded, and the flowers are in a condition suitable for pollination (Fig. 21, 5).
8. *Petal fall*	When the majority of the petals have fallen, but before the calyces have closed (Fig. 21, 6).
9. *Calyx closed*	When the calyces have closed, and the fruits are about 10–12 mm. in diameter (Fig. 21, 7).
10. *Trees in foliage*	Indicates any period between petal-fall and leaf-fall in the autumn.
11. *Leaf fall*	When the leaves begin to fall in late autumn.

In consideration of the fact that all varieties do not develop at exactly the same time, nor do leaves and fruits even on the same tree, it is advisable to apply the spray to trees of one variety when the majority exhibit the stage required. For example, at petal-fall it will be found that many buds on the same tree are not fully expanded; others may be in full bloom; others at the desired condition. Locality has an effect on the period at which the majority of leaves or blossoms are at a certain stage; for instance, trees of the same variety in a hollow may be several days later than those on an adjoining ridge, and certain varieties may be several weeks earlier or later in blossoming than others. Thus it is necessary to consider these facts when carrying out spraying operations.

It is not considered necessary to enter into the details of spraying, for anyone unfamiliar with the process would gain more by studying it in the orchard, but it is perhaps advisable to direct attention to certain features.

For example, unless the material used is well applied to all the fruit and foliage little hope of success can be expected. A nozzle should be chosen which gives a fine mist spray, and the spray should be applied to any part only long enough to cover the leaf or fruit surface, care being used to avoid over-spraying. Attention should be paid to the central growth of a tree, for too frequently is this portion overlooked. The equipment used should be such that no time is wasted in too frequent replenishing of the solution in the tank, for where the orchard area is large and the tank small much time is wasted going to and from the mixing station. This, too, should be situated in a convenient central locality, and the mixing barrels placed on a platform above the level of the tank. The weather conditions should be studied, for it is obvious that spraying in wet weather would be hazardous. Then, too, in high winds quantities of the spray would not reach the tree at all.

SPRAY APPARATUS.

It is obvious that in a book of this nature the relative merits and or demerits of the various makes of spray machines now on the market cannot be discussed. Before purchasing any machine, the orchardist would be well advised to consider the following points, for a machine so equipped would be the most efficient and economical to buy.

The carriage should possess the following features:—

1. Be of light draught.
2. Be easy turning, possessing preferably a full lock.
3. The tank should preferably be provided with an engine-driven filler pump, and should possess an efficient replaceable strainer.
4. Should have a capacity of at least 100 gallons; for any orchard over ten acres this is imperative. (Note.—As the American gallon is less than the British, it is necessary after buying an American machine to determine the actual capacity of the tank in British or Imperial gallons; the American gallon contains 6.6 pints.)
5. It should possess a drain-plug of large dimensions, so that the tank may readily be cleaned.
6. A mechanical agitator is essential; this should preferably be of the screw type.
7. The engine should be covered against wind-blown spray, for any engine trouble rapidly increases spray costs.
8. A spray platform is advisable in orchards where the trees are of large size.

The pump should possess the following features:—

1. Adequate delivery for at least two lines of hose.
2. A reliable, tested pressure gauge.
3. Readily accessible valves and cheaply renewable seatings.
4. Non-corrosive cylinder linings.
5. Leather or composition plunger packings (not metal).
6. Ample size pressure reservoir, tested to 300 lb. sq. in.
7. Geared engine connections (not belt driven).
8. The reservoir must be provided with a relief valve, discharging into the spray tank.

The engine—

1. Should be at least 2½ b.h.p.; for heavy duty work, 3½–5 b.h.p. is preferable.
2. A constant pressure of 200–250 lbs. is essential.
3. Cooling system should be simple and adequate.
4. Adequate lubrication is essential, and sight feeder cups should be fitted to all high speed bearings.
5. The starter handle should be in an accessible position, and should be provided with ample room for its use, thereby minimising the danger of injury to the hands.
6. A first grade magneto is essential; avoid any plant fitted with a battery; the magneto should be gear—not belt—driven.
7. A sensitive, but simply constructed, fool-proof governor is advisable.
8. The fuel consumption should be low.
9. The engine-bed should be low, so as to minimise vibration.
10. A gauge on the petrol tank is useful.

Accessory equipment.

1. A tool-kit chest with ample tools, placed in an accessible position, is desirable.
2. The hose should be of best quality 5–7 ply, preferably ½ in. diam., and should be of ample length, 50–60 feet.
3. Cut-off taps should be provided where the hose connects with the main feed pipes.
4. The nozzle chosen should provide a medium mist spray, and should preferably be of the disc type with readily replaceable discs. (A good test is to direct the spray for a second upon a sheet of paper, from a distance of one foot. The more nearly a solid circle of spray is produced, the better the nozzle for general orchard work.)

It is advisable to wash out the tank and pump with water after use, and this becomes imperative when a spray containing sulphur is to be used after one containing copper (or *vice versa),* or where a spray containing arsenate of lead is to follow burgundy. Doubtless a great deal of the spray injury experienced is due to carelessness in this respect.

Spray-rods should be fitted with angles, so that nozzles are set obliquely, for this facilitates the forcing of the sprays into the pendulous fruits and leaves.

On certain classes of soil, wheeled sprayers may prove too heavy of draught to be widely used; in such a case the barrel type of sprayer may be adopted with profit, in so far as the draught is concerned.

SPRAY SCHEDULES.

Below are given all the spray schedules recommended for the control of the diseases discussed in the systematic part of this work; and, in addition, the spray treatments recommended for the control of insect pests. Standard British weights and measures (in lbs. avdp. and imp. gals.) are used throughout.

POME-FRUIT DISEASE SPRAY SCHEDULES.

SCHEDULE I.:

Control of black-spot, pear-scab, fabraea-scald, apple-spot, and blister-disease.

No.	Time of application.	Spray to use.
1.	Green-tip.	*a.* Bordeaux 5–4–50, or *b.* Lime-sulphur 1–10.
2.	Between open cluster and pink.	*a.* Lime-sulphur 1–30, or *b.* Bordeaux 3–4–50.
3.	Petal fall.	*a.* Lime-sulphur 1–100 to 1–120, or *b.* Bordeaux 3–4–50.
4.	10 days later.	*a.* Lime-sulphur 1–100 to 1–120, or *b.* Bordeaux 3–4–50.
5.	Every month until the fruits reach maturity.	*a.* Lime-sulphur 1–100 to 1–120, or *b.* Bordeaux 3–4–50.
6.	Shortly before picking.	*a.* Lime-sulphur 1–100.

For the control of black-spot, the spray marked (*a*) is to be used in every case; for pear-scab and fabraea-scald, use sprays 1*a*, 2-5 *b*. For blister-disease, only 1*a* is necessary; for apple-spot, No. 6 is recommended, and, in fact, it were advisable to apply this spray to all fruit required for long storage.

Powdery-mildew is not effectively held in check with any of these applications, so that where at all prevalent, the following schedule is preferable:—

SCHEDULE II.:

Control of powdery-mildew.

No.	Time of application.	Spray to use.
1.	Between open cluster and pink.	Lime-sulphur 1–30.
2.	Petal fall.	Precipitated sulphur 10–100.
3.	Early in January.	Precipitated sulphur 10–100.
4.	Middle of February.	Precipitated sulphur 10–100.

No. 4 application is necessary only where the disease is troublesome.

SCHEDULE III.:

Control of insect pests.

This schedule will control, or hold in check, scales, red-mite, codlin-moth, leaf-roller caterpillar, mealy-bug, woolly-aphis, "leech," and thrips.

No.	Time of application.	Spray to use.
1.	Dormant season, shortly before bud movement.	*a.* Red-oil emulsion 1–8 to 1–12, or *b.* Lime-sulphur 1-10.
2.	Petal fall.	*a.* Arsenate of lead, 1½ lb. powder, or 3 lbs. paste to 100 gal. water.
3.	Every month until the fruits reach maturity.	*a.* Arsenate of lead 1½–3–100 + black-leaf 40 + lime-sulphur 1–120.

No. 1 application is for the destruction of scales, red-mite eggs, and woolly-aphis; No. 2 is to fill the calyx with arsenate of lead, thus preventing the penetration through this region of codlin-moth larvae at a later stage; No. 3 holds larval and adult forms of all in check.

SCHEDULE IV.:

Combined spray schedule for the control of insect pests and fungous diseases of pome-fruits.

No.	Time of application.	Spray to use.
1.	Dormant season.	Red-oil emulsion 1-8 to 1-12.
2.	Green-tip.	*a*. Lime-sulphur 1–10, or *b*. Bordeaux 5–4–50.
3.	Between open cluster and pink.	*a*. Lime-sulphur 1–30, *b*. Bordeaux 3-4-50, or *c*. Precipitated sulphur 10–100.
4.	Petal fall.	*a*. Lime-sulphur 1–100 to 1–120, or *b*. Bordeaux 3–4–50. + Arsenate of lead, 1½–3–100.
5.	10 days later.	*a*. Lime-sulphur 1–100 to 1–120, or *b*. Bordeaux 3–4–50.
6.	Every month until the fruits reach maturity.	*a*. Lime-sulphur 1–100 to 1–120, or *b*. Precipitated sulphur 10–100. + Arsenate of lead, 1½–3–100 + Black-leaf 40, 1–800.
7.	Shortly before picking.	*a*. Lime-sulphur 1–100.

No. 1 application need be applied only when scales and red-mite are troublesome; otherwise this spray can be omitted, No. 2*a* taking its place. No. 2*a* may be used when red-oil is not used; otherwise it were preferable to use bordeaux (2*b*). No. 3*a* to be used on apples, 3*b* on pears, 3*c* only when powdery-mildew is troublesome. No. 4 arsenate of lead is necessary for codlin-moth control, and may be combined with 4*a* for apples, or 4*b* for pears. No. 5*a* to be used on apples, 5*b* on pears only. Nos. 2*b*, 3*a*, *b*, 4*a*, *b*, and 5*a*, *b* may be omitted when black-spot is absent from the district, and 2*a* when red-oil is used. No. 6*a*, lime-sulphur + arsenate of lead + black-leaf 40, gives quite efficient control for both insect pests and fungous diseases, and is to be used preferably even on pears, for the combination of arsenate of lead and lime-sulphur gives a fungicide almost as effective as bordeaux; whether black-spot is present or absent, this combination will be necessary for insect control. When mildew is present, it would be advisable to add to two of these sprays precipitated sulphur, 8-10-100. No. 7 is required only when the fruit is to be stored for a considerable time, or when apple-spot is troublesome.

STONE-FRUIT DISEASE SPRAY SCHEDULES.

Owing to the nature of the foliage, bordeaux cannot be used other than at bud movement on these hosts.

SCHEDULE V.:

Control of bladder-plum, brown-rot, die-back, leaf-curl, leaf-rust, peach-scab, and shot-hole.

No.	Time of application.	Spray to use.
1.	Bud movement.	*a.* Bordeaux 5–4–50, or *b.* Lime-sulphur 1–15.
2.	Early pink.	Lime-sulphur 1–50.
3.	Petal fall.	*a.* Lime-sulphur 1–120, or *b.* Self-boiled lime-sulphur 8–8–50.
4.	One month after petal fall.	*a.* Lime-sulphur 1–120, *b.* Self-boiled lime-sulphur 8–8–50, or *c.* Precipitated sulphur 8–100.
5.	Seven weeks after petal fall.	*a.* Lime-sulphur 1–120, *b.* Self-boiled lime-sulphur 8–8–50, or *c.* Precipitated sulphur 8–100.
6.	Shortly before the fruits reach maturity.	*a.* Lime-sulphur 1–120, *b.* Self-boiled lime-sulphur 8–8–50, or *c.* Precipitated sulphur 8–100.
7.	After the fruits have been picked.	*a.* Self-boiled lime-sulphur 8–8–50, or *b.* Precipitated sulphur 8–100.

No. 1 application is necessary for the control of bladder-plum, brown-rot, leaf-curl and leaf-rust. Nos. 4 and 5 are necessary for the control of die-back; Nos. 4-5-6 for the control of peach-scab. With the latter disease, on nectarines, it is necessary to spray a fortnight after petal fall. No. 7 is required only when leaf-rust is troublesome. When brown-rot is absent from a district, Nos. 2 and 3 applications may be omitted; where brown-rot is a serious factor, more satisfactory results will be obtained from the use of self-boiled lime-sulphur; in fact, this has proved a more efficient spray than lime-sulphur for brown-rot, die-back and peach-scab. Precipitated sulphur also is a more efficient controllant of brown-rot than lime-sulphur 1-120.

SCHEDULE VI.:

Control of insect pests: Black and green aphis, red-mite, scale-insects, and "leech."

No.	Time of application.	Spray to use.
1.	Dormant season.	Red-oil 1–12 to 1–15.
2.	Bud movement.	Lime-sulphur 1–15.
3.	One month after petal fall.	Lime-sulphur 1–120 + arsenate of lead 1½–3–100.
4.	Seven to eight weeks after petal fall.	Lime-sulphur 1–120 + arsenate of lead 1½-3-100 + black-leaf 40, 1-800.
5.	Eleven weeks after petal fall.	Do.

No. 1 application is necessary only when scales and red-mite are troublesome; when used, No. 2 may be omitted; if the former is omitted, then No. 2 is advisable. No. 3 readily holds in check red-mite, young scales, and especially "leech." Nos. 4 and 5 hold in check red-mite, scales, "leech," and black and green aphis.

SCHEDULE VII.:

Combined spray schedule for the control of insect pests and fungous diseases of stone-fruits.

No.	Time of application.	Spray to use.
1.	Dormant season.	Red-oil 1-12 to 1-15.
2.	Bud movement.	*a.* Bordeaux 5–4–50, or *b.* Lime-sulphur 1–15.
3.	Early pink.	Lime-sulphur 1–50.
4.	Petal fall.	*a.* Lime-sulphur 1–120, or *b.* Self-boiled lime-sulphur 8–8–50.
5.	One month after petal fall.	*a.* Lime-sulphur 1–120, *b.* Self-boiled lime-sulphur 8–8–50, or *c.* Precipitated sulphur 8–100. + Arsenate of lead, 1½–3–100 + Black-leaf 40, 1–800.
6.	Seven to eight weeks after petal fall.	*a.* Lime-sulphur 1–120, *b.* Self-boiled lime-sulphur 8–8–50, or *c.* Precipitated sulphur 8–100. + Arsenate of lead, 1½–3–100 + Black-leaf 40, 1–800.
7.	Shortly before the fruits reach maturity.	*a.* Lime-sulphur 1–120, *b.* Self-boiled lime-sulphur 8–8–50, or *c.* Precipitated sulphur 8–100.
8.	After the fruit has been picked.	*a.* Self-boiled lime-sulphur 8–8–50, or *b.* Precipitated sulphur 8–100.

No. 1 application is necessary only when scales and red-mite are troublesome; otherwise it may be omitted, and No. 2*b* used in its stead; but where brown-rot is prevalent, it would be preferable to use *2a*, and attempt insect control with the later sprays.

Where brown-rot is absent, it would be advisable to use the lime-sulphur, as this possesses insecticidal properties, and Nos. 3 and 4 may be omitted. No. 8 is necessary only when a special attempt is being made to combat leaf-rust.

For the relative values of lime-sulphur, self-boiled lime-sulphur, and precipitated sulphur, see the note under schedule V., and discussion under each in the section dealing with the chemistry of sprays, p. 70.

CITRUS-FRUIT DISEASE SPRAY SCHEDULE.

SCHEDULE VIII.:

Fungous diseases: Control of citrus-verrucosis, grey-scab and wither-tip.

No.	Time of application.	Spray to use.
1.	At blossom fall of the main crop.	Bordeaux 3–4–50.
2.	At blossom fall of the autumn crop.	Bordeaux 3–4–50.

SCHEDULE IX.:

Insect pests: Control of mealy-bug, scales, red-mite and thrips.

No.	Time of application.	Spray to use.
1.	At or shortly after blossom fall of the main crop.	Red-oil 1–60.
2.	At or shortly after the blossom fall of the autumn crop.	Red-oil 1–60.

SCHEDULE X.:

Combined schedule for the control of insect pests and fungous diseases of citrus-fruits.

No.	Time of application.	Spray to use.
1.	At blossom fall of the main crop.	Bordeaux 3–4–50 + oil-emulsion, 3 quarts.
2.	At blossom fall of the autumn crop.	Do.

Where scales are troublesome, this schedule may have to be supplemented with an additional red-oil 1-60 application.

SPRAY COSTING.

An important factor in disease control is the cost of that control. With a view to obtaining figures on this point, the author forwarded to growers throughout the Dominion schedules drawn up in such a manner that the grower, in filling them in, would give all the necessary information required to compute spraying costs. From the data obtained in this manner, the following figures have been compiled. It is beyond the scope of this book to go into the details of working out these costs; suffice it to say that all overhead costs, such as interest on and depreciation of spray apparatus, repairs, horse costs, labour, running costs, etc., have been dealt with. These have been added to the cost of spray materials, and the figures thus obtained are set out in the following table. The figures are based on the time and materials required to spray large, well-grown fourteen-year-old trees, the amount of material, etc., being obtained from a study of the figures supplied by orchardists.

TABLE OF ACTUAL SPRAY COSTS.

No.	Spray.	Average cost per application.	
		Per tree.	Per bushel (4 bus. per tree).
1.	Lime-sulphur 1–10	4.49d.	1.12d.
2.	Lime-sulphur 1–120	1.92d.	0.48d.
3.	Bordeaux 5–4–50	2.24d.	0.56d.
4.	Black-leaf 40, 1–800	2.65d.	0.66d.
5.	Arsenate of lead (std. str.)	2.06d.	0.51d.
6.	Precipitated sulphur 10–100..	2.57d.	0.64d.
7.	Red-oil 1–10	7.30d.	—
8.	Combined insecticide-fungicide— Arsenate of lead Lime-sulphur Black-leaf 40 Precipitated sulphur	3.93d.	0.98d.

The author believes that this table will give very closely the actual costs of spraying large, well-grown trees, either in the dormant season or under foliage; providing the work is carried out with a minimum waste of time, reasonable prices are paid for materials, and such nozzles are used that the spray is applied in the form of a fine mist; for where coarse nozzles, spray guns, or any such apparatus allowing an undue amount of material to escape, are used, the costs would certainly be much greater than as set out in this table.

With this before him, the orchardist should have little difficulty in computing the cost per tree, and per acre, of his season's spray schedule. Thus, knowing the relative cost of each spray, he may be able to choose those sprays which are the most efficient for disease control, and yet keep his costs within reasonable limits. That such a table is necessary is evidenced by the fact that from the figures supplied, the author has computed that it cost one orchardist 5/3 per tree for his season's spraying!

Where the cost of application per tree is used as the cost unit, the differences from the production point of view are not readily noticeable, for it costs the same to spray a tree bearing one bushel as it does to spray another the same size bearing four bushels. Thus in the previous table, on the right-hand side is a column in which is set out the cost of each spray per bushel, calculated on a 4-bushel yield. This shows that the actual cost *per bushel* of each spray, when applied to trees giving a good yield, is much less than the cost *per tree;* this may be shown in another way, from the consideration of the total cost of the season's spraying. If black-spot is prevalent in a district, the total cost of spraying may come to 20d. per tree, which means that a one-bushel yield would cost the same amount, whereas a four-bushel yield would cost only 5d. per bushel.

SUPERSTITIONS.

For many years past, claims have been made by various people that control of certain diseases may be obtained by treating the trees in some particular manner. For example, a favourite method of "curing" any disease of a tree is to drive iron or copper nails into the trunk. A second method consists of boring a hole in the trunk, and in this cavity inserting such substances as flour, copper or iron sulphate, epsom salts, etc.; another favourite method is to apply to the soil around the bases of the trees, soot, spent calcium carbide (which is simply slaked lime), epsom salts, carbamide, copper or iron sulphate, seaweed, and numerous other substances. More recently we find that leaving affected trees unpruned, or cincturing them near the base of the stem, has been recommended for the control of silver-leaf; or spraying fallen apple leaves while on the ground, recommended in order to minimise black-spot infection. No sufficient experimental evidence has been produced to justify any of these practices.

For literature references, see bibliography, p. 349, numbers *36, 51, 75, 77, 148, 221, 240, 296, 303, 314, 329.*

CHAPTER X.

REMEDIAL TREATMENT.

(Concluded.)

Diseases Overwintering in Dead Host Tissues; Diseases Overwintering in Living Host Tissues; Orchard Sanitation; Picking; Packing.

A necessary branch of disease prevention deals with what may be termed orchard sanitation, or orchard cleanliness. This necessitates the practice of sanitary methods in orchard, packing-shed and cool-store; in fact, the grower should keep his outbuildings as sanitary as any model dairy factory.

Removal of all sources of infection, by means of which fruit-tree diseases overwinter to start the disease afresh in the spring, is just as essential in control as is spraying. This may more forcibly be brought home by the following table, where are set out all those diseases discussed in this work which are capable of overwintering in mummied fruits, dead wood, and dead leaves lying on the ground:—

TABLE I.:

DISEASES OVERWINTERING IN DEAD HOST-TISSUES.

In mummied fruits.	In dead wood.	In dead leaves.
Apple-spot.	Black-rot.	Black-rot.
Bitter-rot.	Coral-spot.	Black-spot.
Black-rot.	Diplodia-canker.	Fabraea-scald.
Brown-rot.	Root-fungus.	Leaf-rust.
Shot-hole.	Silver-leaf.	Pear-scab.
	Valsa-injury.	Shot-hole.
	Wither-tip.	

Theoretically, the destruction of these sources of infection should eradicate the diseases; unfortunately, this is not possible in orchard practice, for leaves are carried to places, such as under hedges, long grass, etc., where they cannot be reached by the plough; and the majority of these diseases are, in addition, carried over on *living* parts of the host. Then, too, there is always the possibility of infection from neglected orchards to consider. But destruction of sources of infection wherever possible tends to reduce infection

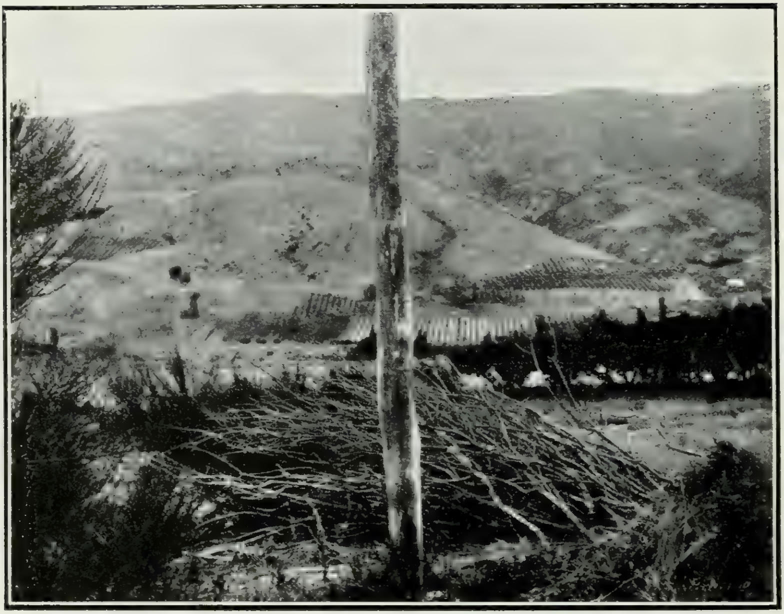

Fig. 22. HEAP OF PRUNINGS THROWN ON TO WASTE LAND AT ROADSIDE; A FRUITFUL SOURCE OF FUNGOUS INFECTION.

Photo by Author.

to such an extent that control by spray treatment is made more feasible. This would be carried out by the orchardist only when it did not call for increased labour or cost on his part. The author, bearing this in mind, recommends that orchard practice be modified, so that as far as practicable these sources of infection be eliminated by—

a. Destruction of mummied fruits. These may be either ploughed under, or, preferably, gathered and buried deeply or burned.

b. Destruction of dead wood. All dead wood should be removed from the trees during pruning, and, together with the other prunings, promptly be burned, not left to lie in heaps (Fig. 22). Trees that have been pulled out, either because of silver-leaf infection or from other reasons, should likewise be burned. Pruning operations should be completed *before* the spring ploughing, for then any prunings left on the ground will be turned under.

c. Dead leaves may be disposed of by ploughing them under, and all portions left under the trees untouched by the plough should be turned over with the spade. Ploughing should be completed at least one month before blossoming commences in the spring. Attention should be paid to the cultivation of headlands, for if left in grass and weeds, they will harbour quantities of dead leaves, fruits and wood. It scarcely need be pointed out that orchards under grass are more liable to infection than those properly cultivated. Cover-cropping is permissible, provided the cover crop be sown after leaf-fall (so that fallen leaves may be turned under) and ploughed under in the late spring; or, if sown in the spring, ploughed under in the summer. Autumn sowing is preferable, for the cover crop may be turned under before it interferes with the use of the spray pump, and the cover crop would tend to act as a blanket, preventing spores being carried to the hosts from the ground.

During pruning, attention should be paid to the removal of dead and weakly shoots, or wood showing the presence of cankers in the cortex.

Numerous orchard diseases overwinter on living wood, as will be apparent by inspection of the following table:—

TABLE II.:

DISEASES OVERWINTERING ON OR IN LIVING LATERALS AND BRANCHES.

Bitter-rot.
Black-rot.
Black-spot.
Bladder-plum.
Blister-disease.
Brown-rot.
Cherry-curl.
Citrus-verrucosis.
Die-back.
Diplodia-canker.
Fabraea-scald.
Fire-blight.
Leaf-curl.
Leaf-rust.
Peach-scab.
Pear-scab.
Powdery-mildew.
Shot-hole.

Cleanliness should be practised equally in the packing shed, for it is probable that at least 50% of losses due to storage rots are directly or indirectly due to infection during handling in the shed. It is impossible to do more than outline the precautionary measures that should be taken to minimise infection, or, what is equally important, to minimise skin injury to the fruit through which soft-rot fungi are enabled to penetrate.

PICKING.

In stone-fruit orchards, where brown-rot is prevalent, go over all trees and remove infected fruit, picking into special receptacles reserved for this purpose, and destroy these fruits by burning or burying deeply. Sterilise the hands by washing with hot water

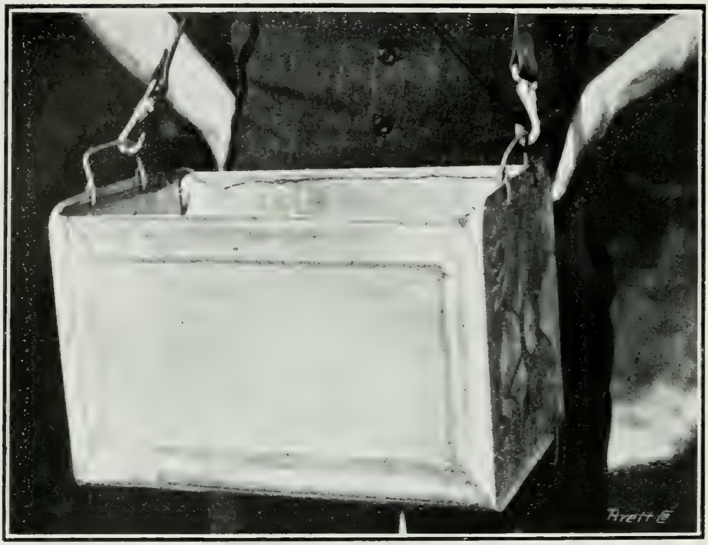

Fig. 23 *a*. "NEILL" PICKING TIN: FRONT VIEW SHOWING CONSTRUCTION.

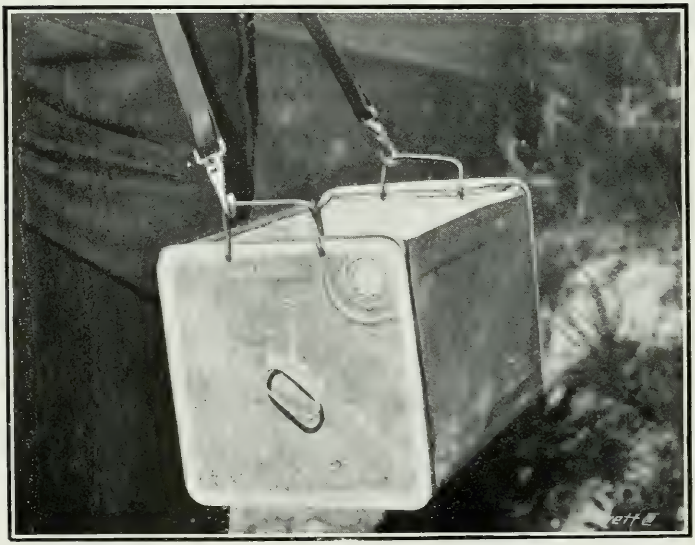

Fig. 23 *b*. "NEILL" PICKING TIN; SIDE VIEW SHOWING HANDLES AND HOLDER CLIPS.

The latter are made from old cow-cover clips from which the springs have been removed.

Photos. H. Drake.

and carbolic soap before picking unaffected fruits. Pick all fruits directly into special receptacles, filling these only about two-thirds full. The most convenient receptacle for this purpose that the author has seen is that used by Mr. J. C. Neill at Weraroa. The accompanying illustrations show the structure and method of handling this tin (Fig. 23). The obvious advantages of the Neill picking tin are:—

1. Cheapness.
2. Lightness, yet the tin is strong enough to withstand rough handling.
3. The method of using saves at least two handlings of the fruit, thus saving 20% of the time required for picking, compared with other methods in use.
4. Both hands are free for picking.
5. The tin is smooth inside, and thus skin injury is minimised.
6. The tin is easily sterilised.
7. Fifty per day may be made, their manufacture being a spare time job.

About 50 tins per picker per day are sufficient if empties are regularly returned with the sled or cart.

The belt being placed around the neck, the picker stoops and clips the two belt clips on to the handles; he then cants the tin at one end, and *places* (not drops) the fruit into the lower end. This saves the fruit from being bruised owing to rolling about in the bottom of the tin. When *two-thirds full* (about 15 lbs. weight), he deposits the tin in the shade of the tree and picks up another from the pile in the vicinity where they are stacked *inverted*. The tins are taken (preferably in a sled, as this minimises bruising) to the shed, and placed on shelves above the packing benches. Stone-fruit should be graded and packed with one handling, direct from the picking tin.

All benches, graders, etc., should be kept clean, and no diseased or rotting fruit should be allowed to lie about in the shed. Before grading, all fruit should be picked over, and *any* showing signs of skin injury placed apart for factory or home use. The grader should be so regulated as to prevent any fruit from falling upon another. No grader bin should be allowed to become full, for it becomes an expensive form of economy to run short-handed. This may be illustrated by the following actual instance. Recently the author had occasion to examine part of three lines intended for export; in the cases examined, from 11% to 21% of the fruits were found to possess skin injuries, and in most cases blue-mould was already present. Investigation of the packing shed, through which these lines came, showed that in this shed they were running short-handed, two packers less than the normal number being used. As a result, the grader bins were all overfull, and apples were dropping from the travellers, not on to canvas, but on to other apples; consequently a large percentage was damaged by stem punctures. One may imagine the condition such a line would open up in the export markets as the result of this false economy.

In all sheds handling stone-fruits, whenever brown-rot is present, it would be advisable to sterilise daily all picking tins and benches, and especially to prevent the entry of brown-rotted fruit to the sheds. Spraying benches with 1-50 lime-sulphur would be an effective means of sterilising them, and the picking tins could be dipped in a tub of the same solution, then stacked upside-down to drain over night.

Enough has been written to show that with a little extra care, store and transit infection from various rots and diseases may be practically eliminated. It is too much to expect that such measures will be adopted immediately, but when the fact is brought home by numerous monetary losses, the orchardist will in time perceive that ordinary sanitary precautions, adopted by every dairy farmer to-day, are equally necessary in the packing shed.

IMMUNITY OF THE HOST.

The ideal method of combating diseases of plants is to produce varieties (or even strains) of fruits possessing all the desirable qualities of susceptible hosts, yet possessing in addition the added quality of being immune to insect and fungus attack. Such a procedure is possible, for there are in existence fruit-trees immune to certain diseases; and with many field crops varieties immune to certain diseases have been produced by selection and crossing. With fruit-trees, the operation would be a slow one, as many years would elapse before results were obtained. It is the author's belief, however, that future "control" measures lie along these lines, and that the future mycologist will, as an additional weapon in his armoury, take up the science of plant breeding.

For literature references, see bibliography, p. 349, numbers *227, 254*.

CHAPTER XI.

WEIGHTS; MEASURES; TEMPERATURES.

METRIC SYSTEM.

MEASURES.

Linear measure.

1000 microns = 1 millimetre (mm.) = 0.039 inch.
10 millimetres = 1 centimetre (cm.) = 0.393 inch.
10 centimetres = 1 decimetre (dm.) = 3.937 inches.
10 decimetres = 1 metre (m.) = 39.37 inches.
1000 metres = 1 kilometre (km.) = 1093.3 yards

Cubic measure.

1000 cubic millimetres = 1 cubic centimetre (cc.)
1000 cubic centimetres = 1 litre (l.)
1000 litres = 1 kilolitre (kl.)
(or 1 cubic metre)

WEIGHTS.

10 milligrams = 1 centigram (cg.)
10 centigrams = 1 decigram (dg.) = 1.54 grain.
10 decigrams = 1 gram (g.) = 15.4 grains.
1000 grams = 1 kilogram (kg.) = 2.2 pounds.

TEMPERATURES.

(32° F., or 0° C. = freezing point: 212° F. or 100° C. = boiling point.)
To convert Farenheit into Centigrade = (F. — 32) × 5/9 = C.
To convert Centigrade into Farenheit = (C. × 9/5) + 32 = F.

MISCELLANEOUS.

Linear measure.

12 lines = 1 inch (in.) = 25.399 millimetres.
12 inches = 1 foot (ft.) = 30.479 centimetres.
3 feet = 1 yard (yd.) = 0.9413 metres.
22 yards = 1 chain (ch.)
1760 yards = 1 mile

Avoirdupois weights.

16 drams = 1 ounce (oz.)
16 ounces = 1 pound (lb.)
14 pounds = 1 stone (st.)
112 pounds = 1 hundredweight (cwt.)
20 hundredweight = 1 ton

Liquid measure.

16 ounces = 1 pint (pt.)
2 pints = 1 quart (qt.)
4 quarts = 1 gallon (gal.)

EQUIVALENT WEIGHTS AND MEASURES.

One grain = 0.064792 gram.
One ounce avdp. = 28.349 grams.
One minim = 0.05916 cubic centimetres.
One fl. ounce = 28.396 cubic centimetres.
One pint = 567.92 cubic centimetres.
One quart = 1.1358 litres.
One litre = 35.2154 fluid ounces.

SECTION II.—SPECIAL.

DISEASES OF FRUIT-TREES AND FRUITS.

CHAPTER XII.

Symptomatology; Table of Pome-Fruit Diseases; Artificial Key to Pome-Fruit Diseases.

This section is divided, for convenience in discussion, into three divisions, as under:—

Division I.	POME FRUITS	(including apple, medlar, pear and quince).
Division II.	STONE FRUITS	(including almond, apricot, cherry, nectarine, peach and plum).
Division III.	CITRUS FRUITS	(including grape-fruit, citron, lime, lemon, orange and pomelo).

It has not been considered necessary further to subdivide these divisions and list the diseases of each host separately, for this would lead to an unnecessary amount of duplication, as, with few exceptions, all diseases discussed herein are common to the majority of the hosts included in each of the divisions enumerated above.

Diseases are arranged in alphabetical order under each division, and are subdivided into three groups, as under:—

(a) *Fungous diseases.*

(b) *Bacterial diseases.*

(c) *Physiological diseases* (under this group are included those obscure diseases, the causes of which are unknown).

To aid the orchardist in diagnosing in the orchard or store any disease with which his trees or fruit may be infected, an artificial key is given at the beginning of the divisions, Pome fruits; Stone fruits; and Citrus fruits.

It is not claimed that these keys will ensure the determination of any disease with certitude; but they do bring together into groups all diseases of a similar nature, thus enabling a comparison to be drawn between individual diseases in any one group.

To combat successfully the diseases with which he has to contend, it is necessary that the orchardist know the *cause* of any disease, for, as will be seen when the systematic part is read, a knowledge of the life-history of the causal organism is essential to its control. In general, it may be said that the orchardist has no means of determining accurately the cause of a disease, and must in consequence rely for a diagnosis of the trouble upon the *symptoms* set up by that disease, for these, as a rule, are so characteristic as to afford a ready means of determination.

SYMPTOMATOLOGY.

For convenience of discussion, symptoms may be grouped as under:—

(a) *Bud-drop and blossom-wilt.*—If at bud movement the buds fall, or if during blossoming certain buds do not expand, or if blossoms suddenly wilt and turn brown, cankers at the base of the buds should be sought for; if present, the trouble will be due to brown-rot or die-back; if absent, then frost injury should be suspected.

(b) *Cankers.*—These appear as dead areas in the cortex of laterals, branches or stems. Numerous fungi may be responsible, according to the host attacked and position of the canker. Sometimes cankers are caused by frost or fire-injury.

(c) *Defoliation.*—This condition arises when the leaves of a tree during the growing season fall away. Defoliation may be partial or total. If this condition is gradual and accompanied by a yellowing of the leaves, otherwise healthy, and the tree presents an unthrifty appearance, root-fungus or unfavourable soil conditions should be suspected. If partial, the condition may be due to leaf-spotting fungi, insects, or spray injury. This condition is so general that it is impossible to do more than indicate the probable cause.

(d) *Die-back of laterals and branches.*—Should laterals on smaller branches die suddenly, the probable cause is fungous attack, especially if accompanied by wilt of the foliage; if death is gradual and the tree presents an unthrifty appearance, then root trouble should be suspected. The nature of the trouble would further be indicated by the appearance of the leaves.

(e) *General debility.*—This condition is indicated by an unthrifty appearance; the tree makes little or no growth, and bears little or no fruit; the leaves are usually yellowish in colour, and few in number.

The roots and stem should be examined; if disease is absent from these portions, then the trouble may be considered to be a soil one.

(f) *Fruit-rots.*—This condition is indicated by a general rotting of the fruit, the normal flesh becoming some shade of brown. Rotting may occur externally or internally, and may be induced by fungi, bacteria or unfavourable cold-storage conditions.

(g) *Gumming.*—The presence of exudations of gum on the branch or stem of a tree is an indication that some trouble is present. If the tissues in the vicinity are dead and discoloured, one or more fungi are responsible; if normal and the gum is confined to small "pockets," then the trouble is a physiological one (see gummosis).

(h) *Leaf-discolouration.*—Many agencies may cause a discolouration of the leaf, as, for example, spray injury, insect or fungous attack, or unfavourable soil conditions. If the leaves are silvered, the tree may be infected with silver-leaf; if yellowed, look to the roots. If these are diseased, then root-fungus or collar-rot is the cause; if normal, the trouble is probably a soil one; if the leaves are tinted purple and curled, the trouble is either spray injury or more probably insect attack.

(i) *Leaf-perforation.*—If clean-cut perforations are present, the trouble is due to shot-hole or die-back; if poorly defined, then brown-rot or peach-scab is the probable cause.

(j) *Malformations of fruit or leaves.*—When immature plum fruits become large and hollow, they are infected with bladder-plum; if apple fruits are distorted, and show numerous discoloured spots in the flesh, they are affected with bitter-pit; if citrus fruits are malformed, as is shown in the illustration on p. 347, the trouble is due to some unfavourable strain.

If leaves are blistered and curled, they are infected with leaf-curl, cherry-curl or bladder-plum, according to the host.

(k) *Mildew.*—When the leaves and laterals appear as if dusted with flour the trouble is due to powdery-mildew.

(l) *Spots and scabs on the leaves and fruits.*—These are invariably due to insect or fungous attack. They may on the fruit be internal (when they are usually due to bitter-pit) or external, and may be black, brown or brightly coloured.

(m) *Tumours.* Swellings on the roots or crown are due to root-knot or woolly-aphis injury; on stems or branches they are usually due to woolly-aphis.

(n) *Wilt.*—This condition is indicated by a sudden wilting and browning of the leaves; if on one or more shoots, cankers should be looked for at the base of the shoot; if on stems, look for cankers at the base of the stem; if the whole tree wilts suddenly, examine the roots; if diseased, suspect root-fungus or collar-rot; if apparently normal, the trouble may be due to excess or lack of water.

DIVISION I.—POME FRUITS.

(Apple, Medlar, Pear, Quince.)

The following table shows at a glance which diseases, in New Zealand, occur on the various hosts included under this division:—

HOSTS.

Page.	Apple.	Pear.	Quince.	Medlar.
197	Apple-scald	—	—	—
107	Apple-spot	—	—	—
199	Bitter-pit	Bitter-pit	Bitter-pit	—
110	Bitter-rot	Bitter-rot	Bitter-rot	Bitter-rot
118	Black-rot	Black-rot	Black-rot	—
123	Black-spot	—	—	—
137	Blister-disease	Blister-disease	—	—
143	Brown-rot	Brown-rot	Brown-rot	—
145	Circular-spot	—	—	—
147	Diplodia-canker	—	—	—
152	—	Fabraea-scald	Fabraea-scald	—
189	Fire-blight	Fire-blight	Fire-blight	Fire-blight
205	Flesh-collapse	—	—	—
209	Frost-injury	Frost-injury	—	—
210	Glassy-core	—	—	—
213	Jonathan-spot	—	—	—
214	Mouldy-core	—	—	—
160	—	Pear-scab	—	—
162	Powdery-mildew	—	Powdery-mildew	—
170	Root-fungus	Root-fungus	Root-fungus	Root-fungus
196	Root-knot	Root-knot	Root-knot	—
176	Silver-leaf	Silver-leaf	Silver-leaf	Silver-leaf
177	Soft-rots	Soft-rots	Soft-rots	Soft-rots
216	Sour-sap	Sour-sap	—	—
218	Stag-head	Stag-head	Stag-head	Stag-head
219	Sun-scald	Sun-scald	—	—
187	Valsa-injury	—	—	—

ARTIFICIAL KEY TO POME-FRUIT DISEASES.

A key, such as the following, although it looks complex, is in reality very simple to use.

For example, an orchardist finds a canker to be present in the branch of an apple tree, and desires to determine the probable cause. He looks for the term "canker" in the key (under A.).

Under this heading he finds two sections—

Canker zoned.
Canker not zoned.

Say the canker is zoned, he then looks under "canker zoned," and finds—

Zones of concentric crevices.
Zones of light and dark bands of colour.

Should the canker be zoned with concentric crevices, he knows that it has been caused by black-rot; if not, then it is due to diplodia-canker.

It thus becomes apparent that he has arrived at the cause of the canker by a process of elimination, and this process is applied throughout the key. In many cases it is difficult in a key of this nature to indicate with any degree of accuracy the exact characters of a disease; in many cases, indeed, it is only possible to do this with the aid of cultures and the microscope. Again, many diseases differ in appearance according to the host, or portion of the host, they may happen to attack; thus in the key the same disease will sometimes be found listed under two or three headings.

Whenever the reader is in doubt, he is advised to consult the text and illustrations in the following pages.

A. CANKER PRESENT ON BRANCH OR LATERAL.

Canker zoned.
Zones of concentric crevices .. .. .. *Black-rot* (p. 118)
Zones of light and dark bands of brown colour .. .. *Diplodia-canker* (p. 147)

Canker not zoned.
Canker depressed .. .. *Bitter-rot* (p. 110)
Canker superficial .. .. *Fire-blight* (p. 189)

B. HOST DEBILITATED.

Leaves silvered .. .. *Silver-leaf* (p. 176)

Leaves yellowed.
Roots more or less decayed .. .. .. *Root-fungus* (p. 170)
Roots apparently healthy .. .. .. *Soil trouble* (look to drainage)

C. FRUIT DECAYED OR ROTTED.

Rot apparent externally.

Fructifications not apparent on surface.

Entire fruit rotted.

Fruits black, wrinkled.
Surface smooth, glossy .. .. *Brown-rot* (p. 143)
Surface minutely roughened with papillae .. .. .. *Black-rot* (p. 118)

Fruits brown, ooze globules frequently present .. .. .. *Fire-blight* (p. 189)

Portion only of fruit rotted.
Lesions yellowish .. .. .. *Delicious-spot* (p. 185)
Lesions dark-brown .. .. .. *Apple-scald* (p. 197)

Fructifications apparent on surface.
Fructifications blue-green .. *Blue-mould* (p. 178)
Fructifications grey .. .. .. *Botrytis-rot* (p. 182)
Fructifications pink, frequently concentrically arranged .. *Bitter-rot* (p. 110)
Fructifications black .. .. .. *Rhizopus-rot* (p. 187)

Rot internal, not or seldom apparent externally.
Rot affecting core .. .. .. *Mouldy-core* (p. 214)
Rot confined to pulp cells .. .. *Flesh-collapse* (p. 205)

D. LEAF DISCOLOURATION.

Leaves silvered .. .. *Silver-leaf* (p. 176)

Leaves yellowed.
Roots more or less decayed .. .. . *Root-fungus* (p. 170)
Roots apparently normal .. .. .. *Soil trouble*

E. MILDEW PRESENT ON LEAVES AND LATERALS .. .. .. *Powdery-mildew* (p. 162)

F. SPOTS AND SCABS ON LEAF, FRUIT OR BRANCH.

On branch and lateral.		
Spots covered by epidermis, bullate, olivaceous	*Blister-disease*	(p. 137)
Spots exposed, creviced, brown or black	*Black-spot* *Pear-scab* *Fabraea-scald*	(p. 123) (p. 160) (p. 152)
On leaves.		
Spots circular, ochraceous	*Circular-spot*	(p. 145)
Spots irregular.		
Spots brown, with reddish or purplish border	*Fabraea-scald*	(p. 152)
Spots black, velvety	*Black-spot* *Pear-scab*	(p. 123) (p. 160)
On fruits.		
Spots circular, or almost so, definite.		
Spots superficial.		
Spots brightly coloured.		
On apples	*Apple-spot*	(p. 107)
On pears	*Fabraea-scald*	(p. 152)
Spots black or brown.		
Fructifications present, obvious	*Black-spot* *Pear-scab*	(p. 123) (p. 160)
Fructifications not noticeable or absent.		
On apples	*Jonathan-spot*	(p. 213)
On quinces	*Fabraea-scald*	(p. 152)
Spots immersed, scattered through pulp cells	*Bitter-pit*	(p. 199)
Spots irregular, scabbed or russetted, indefinite.		
Crevices present.		
Crevices concentric	*Blister-disease*	(p. 137)
Crevices irregular	*Black-spot* *Pear-scab*	(p. 123) (p. 160)
Crevices absent, russetting present	*Powdery-mildew*	(p. 162)

G. TUMOURS PRESENT.

On roots	*Root-knot*	(p. 196)
On branches and stem	*Woolly-aphis*	

H. WILTING OF LEAVES.

On laterals and branches	*Fire-blight*	(p. 189)
On laterals only	*Diplodia-canker*	(p. 147)
On whole tree	*Sour-sap*	(p. 216)

CHAPTER XIII.

POME-FRUIT DISEASES.

(a) *Fungous Diseases.*

APPLE-CANKER, Nectria galligena Bresadola.

This fungus, under the name of *Nectria ditissima* Tul., has been recorded as being parasitic on the apple in New Zealand *(186; 198)*, but it is extremely doubtful whether it occurs here, for all cankers supposed to be due to this organism, and examined by the author, have in reality been caused by black-rot, *Physalospora Cydoniae.*

As the term apple-canker should be retained for the disease caused by *Nectria galligena,* it will be necessary to abandon the term "canker," which in the past has so regularly been applied to all large open wounds of fruit-tree branches and stems irrespective of the cause.

APPLE-SPOT, Phoma Pomi Passerini *(232)*.

Syn.: *Cylindrosporium Pomi* Brooks *(53)*.
Fruit-spot; phoma fruit-spot; quince-blotch.

This is comparatively a minor disease, for in New Zealand it has been found only on the fruit of the apple, although in North America it has been recorded in addition upon fruits of the quince, Chinese quince *(Cydonia sinensis)*, and japonica *(Cydonia japonica)*. It appears to be abundant in certain of the United States of America, and has been recorded also from Germany; it was first recorded for New Zealand in 1921 *(109)*.

APPEARANCE AND EFFECT UPON THE HOST.

On the fruit it forms small spots, which become noticeable towards the middle of March, seldom earlier, but especially on fruits after they have been for a time in cool-store. The spots at first are brightly coloured, quite small, seldom more than 2-5 mm. in diameter, and are usually more prevalent towards the blossom end of the fruit. As the fruit colours, the spots become conspicuous, as they are then seen to be surrounded by a brilliant reddish

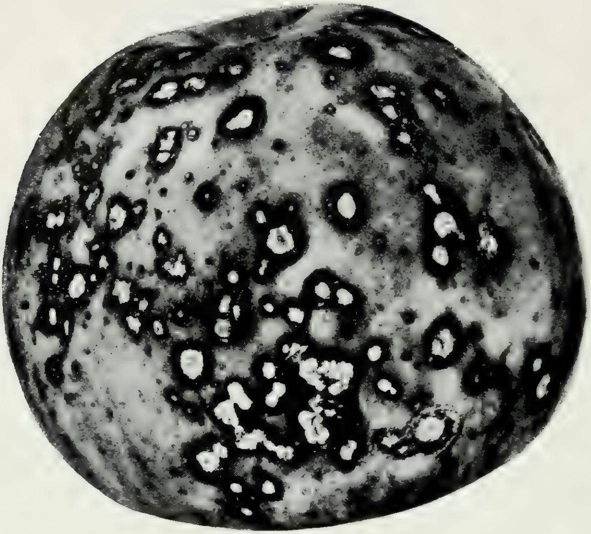

Fig. 24. APPLE-SPOT. Natural size.

The zones around the central white spots are coloured red in nature. This is not a typical illustration of the disease in that the cuticle has become lifted over the spots, giving to them their white appearance.

Photo, E. Bruce Levy.

margin (Fig. 24). After the fruit has been stored for some time, the spot becomes slightly sunken below the surface, and changes in colour to some shade of brown. Sections through a spot show that a small brown zone is present beneath the discoloured epidermis, but as this area does not extend more than about 5 mm. into the fruit, the disease is not of great economic importance, since it does not materially affect the market value of the fruit.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Apple-spot is caused by *Phoma Pomi,* a fungus possessing three spore stages in its cycle.

Fruits become infected late in the season, usually as they are approaching maturity. Should a spore at this period be carried to the fruit, and conditions prove favourable, it may germinate and produce an infection hypha which apparently is able to penetrate into the host-tissues only through a stoma; hence, as stomata occur more frequently at the blossom end of the apple, the spots appear in greater numbers in this region. Once the hypha has entered the fruit it ramifies between the cells in the vicinity of the point of entry, and branches repeatedly until a small mass of mycelium is formed beneath the epidermis. The cells in the vicinity are killed by the fungus, turn brown, and form a discoloured spot noticeable on the exterior. After a time the host-tissues collapse slightly, and the surface of the spot becomes correspondingly depressed. From the mycelial mass are produced small fructifications, which, as they develop, rupture the overlying epidermis and become visible on the surface of the spot as small black elevations.

These fructifications may be of two kinds: the first are small, irregularly shaped bodies, producing from their free surfaces numerous filiform or cylindrical, 3-5 celled, colourless conidia (*Cylindrosporium* stage); the second, an irregular, globose or elliptical pycnidium, from the inner surface of which are produced minute, one-celled, colourless spores (*Phoma* stage). The first spore-form appears to be more abundant in nature, and is not only produced on the structures described above, but frequently is formed from hyphae within the tissues of the fruit. These spores are short-lived, and serve to infect other fruits in the vicinity. As six weeks or more elapse between the time of infection and the first appearance of the disease, the disease may not manifest itself until after the fruit has been some time in store.

As the conidia are short lived, it is obvious that the organism must have some means of carrying over from one season to the next, for so far as is at present known, it does not occur on leaves or shoots, being confined to the fruits. American authorities claim that this is effected either by means of resting mycelium or chlamydospores living through the winter and spring in old mummied apples lying on the ground or hanging on the trees. Chlamydospores occasionally are found in the infected tissues, appearing as irregular, globose or elliptical, thick-walled bodies produced from the terminal ends of short hyphae. From the resting mycelium in the mummies fructifications are produced, and these in turn give rise to conidia, which, on being carried by wind or other agency to maturing fruits, commence the cycle anew.

CONTROL.

It has been shown that the disease overwinters in mummied fruits hanging on the trees or lying on the surface of the ground; thus it would appear that the removal of these sources of infection would prevent a recurrence of the trouble. Unfortunately, in those areas where this practice has been followed, the disease still is present to a greater or less extent, so that we are led to seek some additional means whereby the disease may be combated. Fortunately American experience has shown that the disease regularly is controlled with an application of a fungicide shortly before the fruits mature. For this purpose an application of 1-100 lime-sulphur is recommended, especially when the fruits are to be stored for any length of time. In those areas where black-spot is prevalent, this spray will be applied in any case, so that no additional precautions need be taken to prevent infection from apple-spot.

SUMMARY.

1. Apple-spot is a fungous disease confined to the fruit of the apple, and elsewhere has been found on the quince and Chinese quince and *Cydonia japonica*. It has not been found on leaves or shoots.

2. It forms a small, circular, usually brightly coloured spot on the epidermis of the fruit, noticeably on the variety Sturmer.

3. Three spore stages occur in its cycle, but one or more may be absent; the first *(Cylindrosporium* stage) is produced from mycelial masses or from hyphae; the second *(Phoma* stage) is produced within pycnidia; the third appears in the form of chlamydospores.

4. The fungus overwinters on mummied or decaying apples remaining on the trees or lying on the surface of the ground.

5. Control measures consist in the removal of these mummied fruits, and in applying a 1-100 lime-sulphur spray about three weeks before the fruit reaches maturity.

For literature references dealing with this disease, see bibliography, p. 349, numbers *53, 55, 56, 109, 232.*

BITTER-ROT, Glomerella cingulata (Stonemn.) Spaulding and v. Schrenck *(310)*.

Syn.: *Gnomoniopsis cingulata* Stonemn.; *Glomerella rufomaculans* Sp. et v. Schr.; *Gloeosporium fructigenum* Berk.; *Gloeosporium rufomaculans* (Berk.) Thuem.; *Colletotrichum gloeosporioides* Penz.

Anthracnose; bitter-rot canker; ripe-rot.

In the United States of America bitter-rot is considered to be one of the most serious of all diseases of the apple, ranking second in importance only to black-spot. It appears to have spread from that country to Europe, Asia, England, and Australia. In New Zealand it has a somewhat restricted distribution, for although prevalent in both orchard and store in Auckland province, it is present as a rule only in store in Nelson and Hawke's Bay provinces, has been occasionally seen in Wellington and Canterbury, and is unknown in Central Otago.

In New Zealand it has been found on the apple, pear, quince, lemon, orange, mandarin and pomelo, but elsewhere it is not con-

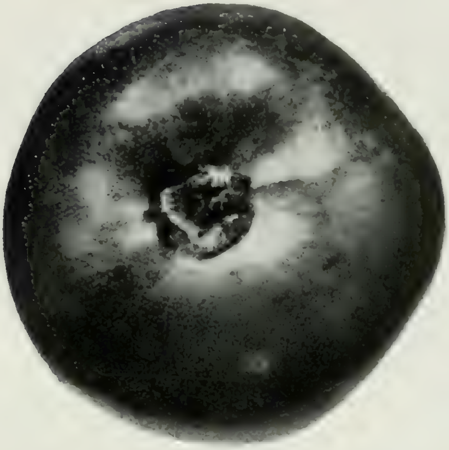

Fig. 25. BITTER-ROT LESION ON APPLE FRUIT. × ½.
Incipient infection of the calyx.

Photo, H. Drake.

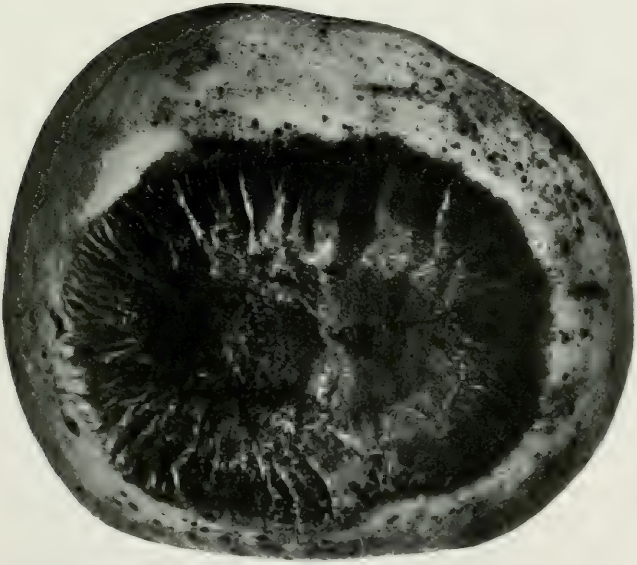

Fig. 26. BITTER-ROT INFECTION ON APPLE FRUIT. × ⅔.
Apple partially rotted; the numerous black spots around this decayed area indicate other infection points.

Photo, E. Bruce Levy.

fined to these hosts, for in North America *(280)* it has been recorded on 34 hosts, among which may be mentioned black raspberry, Camellia, fig, gooseberry, hawthorn, New Zealand Phormium *(Phormium tenax* Forst. f.) and privet.

The conidial stage of the disease was first recorded for New Zealand in 1906 by Kirk *(187)*; the ascigerous stage was found (but not recorded) by the author in 1920.

APPEARANCE AND EFFECT ON THE HOSTS.

Bitter-rot attacks the fruit and branches of the apple, pear and quince, completely destroying the fruit, and forming cankers on the branches.

On the fruit the disease may make its appearance when it is little more than half grown, or may not become apparent until the fruits are nearly mature, or in certain localities, may not be noticeable in the orchards at all, but appear only after the fruit has been placed for a time in store. The first sign of the disease on the fruit is the appearance of a small, light-brown spot which rapidly increases in diameter, appearing at the end of three or four days as a circular area 25 mm. or more across (Fig. 26). During its development the spot usually remains circular in outline, the diseased portion is firm to the touch, and although at first a light brown, soon changes until it may appear almost black. As the spot increases in size, the centre gradually sinks below the level of the surface of the fruit, appearing as a crater-like depression. Frequently the surface appears zoned with light and dark bands of brown, arranged in a concentric manner. Within a few days after the spot has become visible, small blisters appear near the centre, arranged in circles or else scattered irregularly beneath the epidermis. These blisters increase in size, the epidermis becomes ruptured, and the pink, gelatinous spore masses become exposed. Usually the zones of colour are replaced with concentric rings of these spore masses; these later may merge and obliterate the concentric arrangement, which is thus as a rule noticeable only in the earlier stages of infection (Fig. 27). The disease may continue to spread until the whole fruit is rotted, or may, after a time, cease to spread, when it is confined to a portion only of the fruit.

The circular nature of the spots, their dark colour and the concentric rings of spore masses (Fig. 27), are the diagnostic characters by which this disease may be determined in the field. The disease derives its common name from the fact that the diseased tissue is supposed to possess a bitter taste, but this is not always the case, for this taste is frequently wanting, the flesh being merely insipid.

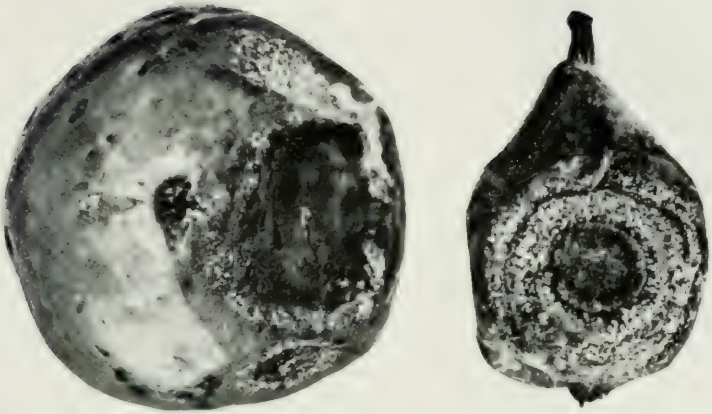

Fig. 27. BITTER-ROT ON APPLE AND PEAR FRUITS. ½.
Note the concentric arrangement of the fructifications of the causal fungus on the pear (right).

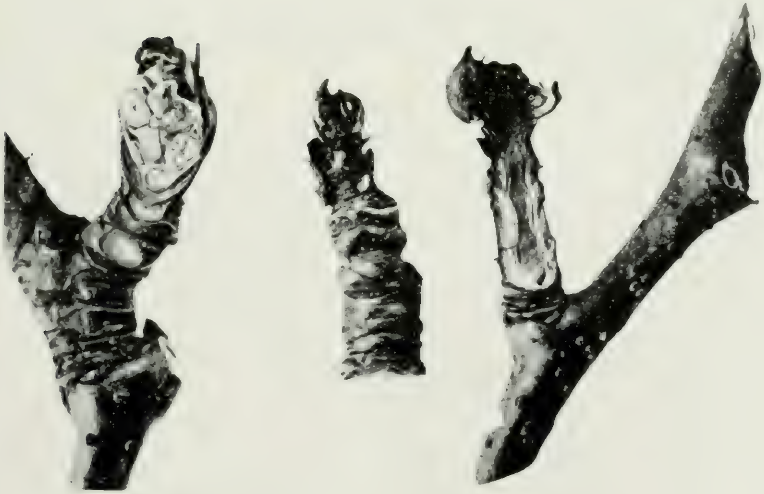

Fig. 28. BITTER-ROT ON BLOSSOM BUDS. × 2.
Healthy buds on the left. Note the manner in which the buds have been destroyed.

Photos. H. Drake.

On branches irregular cankers are occasionally formed. Although this condition would appear to be fairly abundant in the United States, with us it is rare, for of the many hundreds of canker specimens forwarded to the laboratory only two have been due to this organism. In appearance these cankers are so similar to those caused by the black-rot organism, that it is only by microscopic examination or cultures that the two may be separated. The canker is usually elliptical in outline, and consists of a dead, slightly sunken area of bark, darker in colour than the normal bark, closely adhering to the underlying wood, which is killed for some little distance below the surface. On old cankers the bark frequently is zoned by numerous crevices which run parallel with the edge of the canker.

Recently the author isolated the organism causing bitter-rot from diseased blossom buds of pears. Apparently normal blossom buds, when sectioned, were found to be blackened and partially destroyed, the individual flower buds being so damaged as to be almost unrecognisable (Fig. 28). The covering envelope of leaves and scales appeared to be quite healthy, but often partially expanded, the diseased buds being then plainly discernible on the tree. Numerous cultures were made from the diseased buds, and in every instance fructifications morphologically identical with the bitter-rot organism were obtained. These were innoculated into apple fruits, and produced lesions characteristic of this organism. Recently a quantity of mature pears, badly infected with bitter-rot, was received in the laboratory; these had been picked from the same tree from which the diseased buds were obtained. This disease has not been found on leaves in nature.

ECONOMIC IMPORTANCE.

The chief source of loss through this disease is due to the rot of the fruits, for the cankers are so rare with us as to be a negligible factor. With the exception of the Auckland province, bitter-rot does not do much damage to the fruit in the orchards, but is the cause of a serious loss in transit, in store and in the markets, for fully 10% of storage and market losses are due to this disease. In the orchards of the Auckland province the disease, in certain seasons, particularly in warm, moist seasons, may cause 1% (or more) loss to the apple and pear grower.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Bitter-rot is caused by *Glomerella cingulata,* a fungus possessing two spore stages in its life-cycle. The first or conidial stage is the actively parasitic one, the second or ascigerous stage apparently playing little part in the perpetuation of the organism.

From infected mummied fruits of the previous season, from cankers and other sources, conidia are produced which are carried to developing fruits in the vicinity by rain, insects and possibly birds *(257)*, wind playing but a minor part in spore dissemination. Here, should conditions of temperature and humidity prove favourable, the conidium germinates and produces an infection hypha which penetrates the epidermis of the fruit either directly or through some injured surface, and enters the host tissues, where it branches repeatedly to form a mycelium, the hyphae of which ramify through the cells, killing them in advance by the secretion of certain substances. Near the point of infection and beneath the epidermis the hyphae within a few days become aggregated into compact masses, from which arise numerous, slender, upright conidiophores, closely compacted together in palisade fashion. This hyphal mass, together with the palisade of conidiophores, is termed an acervulus (Fig. 29*a*). From the free ends of the conidiophores, conidia are abstricted. These are produced in such numbers that they push up the overlying epidermis into a small blister-like elevation, which ruptures and exposes the masses of spores. In mass the conidia are pink, and have a glistening appearance due to the presence of a mucilaginous substance in which they are embedded. This substance tends to hold the conidia together, so that if conditions favourable to spore production continue, these spore masses may be seen to assume the form of small tendrils.

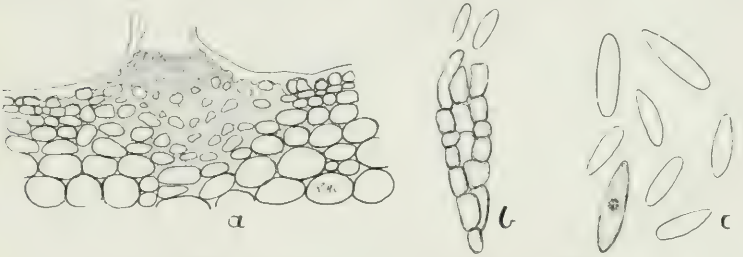

Fig. 29. FRUCTIFICATIONS OF GLOMERELLA CINGULATA.
a. Acervulus on apple fruit; *b*. portion of acervulus showing structure, and palisade arrangement of the conidiophores; *c*. conidia.
a. × 85; *b*. × 300; *c*. × 500.

Original.

So rapid is the development of this organism, that within three to six days after infection, further conidia may be produced on the surface of the infected portion of the fruit. The gelatinous matter is readily dissolved in water, and the spores, thus freed, may be carried by rain or insects to other fruits in the vicinity. Or, should spores be carried to some wound on a branch, they may germinate and give rise to a canker, through the hyphae penetrating into and killing the tissues of the wood and bark. In these tissues the fungus spreads much more slowly than it does in the fruit, so that a canker may be several years of age before it has attained to any size. It would appear that the fungus cannot directly penetrate through the bark, but is able to gain entry to the bark and wood tissues only through some injured surface. Cankers on young two or three-year-old branches are usually short-lived, but those on older branches have been known to persist for 15 or more years. During the growing season, in moist, warm weather, conidia may be produced from the surfaces of viable cankers, and occasionally the second or ascigerous stage may be found in the dead bark of these necrosed areas. This stage is apparently rare, and probably plays little part in the perpetuation of the disease; it consists of perithecia, asci and ascospores, similar to those described under black-rot (p. 124), save that the perithecia are grouped together in small black masses of 3-4 or more. The asci and ascospores are evanescent and last but a short time after they have been formed. This ascigerous stage has also on occasion been found in mummied fruits.

CONSIDERATIONS REGARDING CONTROL.

Conidia are short-lived, yet if a spore mass is allowed to dry out, until it has assumed a horny consistency, the spores may remain viable for many months *(71)*. Numerous workers have shown that infected fruits, if allowed to remain on the tree or on the surface of the ground, are a source of infection the following spring, for numerous acervuli producing conidia are formed from the mycelium within the tissues.

Cankers are a source of infection, for the mycelium therein is capable of producing conidia during the growing season, and may on occasion give rise to asci and ascospores.

Roberts *(256)* has shown that the fungus may overwinter on almost any cankered or dead portion of the bark or wood of a tree, for he found it to be present on various cankers caused by fire-blight, black-rot and other organisms, dead tips of fruit spurs, and on injured branches. In these areas it lives in the mycelial form, and in the growing season may give rise to acervuli producing conidia. Finally, the author has shown that the organism may overwinter in the blossom buds.

CONTROL.

From the foregoing it is seen that this disease may overwinter in cankers, mummied fruits, crevices in the bark, dead tips of laterals and fruit spurs. Therefore it would appear that the first consideration in attempting control is to remove so far as is possible these sources of infection. American experience is, that if this procedure is adopted, and this treatment supplemented by spraying, the disease may be combated effectively.

Therefore remove all cankered branches, and paint over with coal tar the wounds thus formed; remove all mummied fruits from the trees and surface of the ground, and destroy by burning or burying deeply. Spray infected trees, and trees in the vicinity at bud movement with bordeaux 5-4-50; this would destroy any mycelium hibernating in bark crevices, old scars, etc. Follow with the spray schedule (p. 85), but with pears replace the lime-sulphur sprays with 3-4-50 bordeaux, for American experience has shown that lime-sulphur is not an efficient controllant of this disease. Unfortunately one cannot recommend bordeaux for a summer spray of apples, as severe russetting of the fruit would be certain to follow its application.

Before storing fruits cull all apples showing signs of bitter-rot, and if the disease is at all prevalent it would be advisable periodically to go through all stored fruit, for the disease is transmissible by contact, and if one or more infected fruit were present in a case they would soon infect the remainder.

SUMMARY.

1. Bitter-rot is a disease caused by the fungus *Glomerella cingulata*; it attacks apples, pears and quinces, and numerous other hosts.

2. It forms a brown rot on the fruits, and a canker on the branches.

3. Two spore stages are present in its life-cycle, a conidial and an ascigerous stage; the former is the common one, appearing on infected fruits, cankers and on mummied fruits; the latter is rare in nature, but occasionally is found in the dead bark of cankers and in mummied fruits.

4. The organism overwinters in mummied fruits, cankers on the branches, and in old scars, wounds and abraded surfaces of branches, damaged blossom buds and dead tips of laterals.

5. Control measures consist in the removal of the sources of infection, and the application of certain fungicides.

For literature references dealing with this disease see bibliography, p. 349, numbers *71*, *88*, *187*, *256*, *257*, *258*, *260*, *280*, *299*, *310*.

BLACK-ROT, Physalospora Cydoniae Arnaud *(27)*.

Syn.: *Diplodia Malorum* Fcl.; *Diplodia pseudodiplodia* Fcl.; *Sphaeropsis Malorum* Berk.; *S. Malorum* Peck; *Macrophoma Malorum* (Berk.) Berl. et Vogl.; *Physalospora Malorum* (Berk.) Shear.

Apple-canker; black-rot canker; black-rot leaf-spot; blossom-end rot; body-blight; body-canker; brown-rot; brown-spot; frog-eye; leaf-spot; New York apple-tree canker.

This disease has been recorded from North America, Europe and Australia. In certain parts of North America it is considered as a serious parasite of the apple, but in Europe and New Zealand it is comparatively a minor disease. In New Zealand it is the common canker of apple and pear, and in North America has been recorded *(161)* on 41 additional hosts, among which may be enumerated apricot, cherry, currant, grape, hawthorn, peach, plum and rose. In early Departmental Reports cankers caused by it were attributed to apple-canker, *Nectria galligena,* but fortunately this fungus is not known to occur in the Dominion.

The conidial stage was first recorded for New Zealand by Kirk *(188)* in 1907; the ascigerous stage by the author *(121)* in 1922.

APPEARANCE AND EFFECT ON THE HOSTS.

Black-rot infects shoots and branches, fruits, and leaves. On the laterals and branches, but more frequently on the latter, it forms definite cankers. These at first appear as small elliptical areas, noticeable on account of their colour differing from that of the healthy bark. Shortly after its formation the cankered area becomes separated from the normal bark by a crevice. Then the diseased bark shrinks so that the canker appears slightly sunken (Fig. 30). Usually the healthy bark at the margin of the canker becomes slightly raised, due to the development of corky tissue in this region. The diseased area then becomes lighter in colour, and consequently more conspicuous. Growth of the fungus proceeds in a radiate manner, so that invariably in old cankers there are present numerous crevices, arranged in zones, which have been formed as successive layers around the canker. These render the canker conspicuous and readily discernible; further, they serve as quite a good character to separate black-rot cankers from those formed by other diseases (Fig. 31). Cankers may continue to grow for several seasons, or until the branch is ring-barked, when the portions above die. Death is often preceded by a gradual yellowing of the leaves, which usually fall prematurely. The bark sometimes falls away from old cankers and exposes the wood.

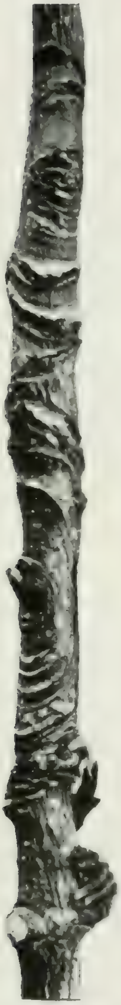

Fig. 30.

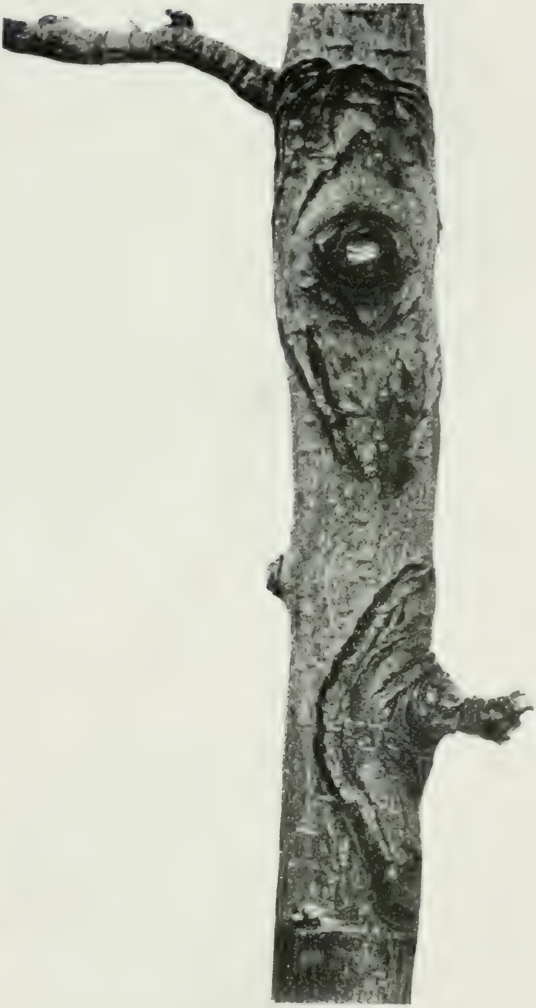

Fig. 31.

Fig. 30. BLACK-ROT CANKER ON ONE-YEAR-OLD LATERAL OF PEAR. Natural size.

Point of entry through dead leaf buds; note the concentric crevices characteristic of this disease.

Photo by Author.

Fig. 31. BLACK-ROT CANKER ON PEAR BRANCH. Natural size.

Point of entry through dead fruit spur.

Photo. W. D. Reid.

Sections through a canker on a medium-sized limb show that the sap-wood is discoloured for some distance beyond the visible point of infection, and microscopic examination reveals the presence of hyphae of the fungus in this discoloured area. On large limbs girdling may not occur, the fungus in such a case forming large irregular cankers, which may attain a length of 4 dm. (1 ft.) or more. Some time after a canker has been formed fructifications of the fungus appear on the surface of the killed area.

Spots become noticeable on the leaves shortly after they emerge from the bud, and infection may occur during the whole of the growing season should conditions be favourable. At first the spots are minute, circular, scattered, and dark purple in colour. They soon increase in size, growth proceeding in a radiate manner, so that the centre portion (the original spot) may appear surrounded by definite zones. Later this central portion changes to greyish-brown, and as the surrounding zones are darker, these spots present a characteristic appearance, which has led to the name "frog-eye" being applied to them. Finally, spots may lose their circular outline and become lobed and irregular in shape. In cases of severe infection the spots may become so numerous as to coalesce, forming irregular dead areas on the leaf. Severe infection may be followed by defoliation.

Fruit-infection is followed by the appearance on the surface, of small circular brown areas; these rapidly increase in size until the whole fruit becomes rotted. As these areas enlarge, zoning may occur, as in the case of leaf-infection, but this is not a common manifestation of the disease. Infected fruits do not become soft, but remain firm and spongy. Finally the colour changes to jet-black, and the fruit gradually shrivels and becomes mummied (Fig. 33).

ECONOMIC IMPORTANCE.

Although in certain parts of the United States black-rot is a serious disease, causing an annual loss of several hundred thousand dollars, in New Zealand it is of minor importance, its chief damage being due to the cankers it forms on the branches of apple and pear trees. On leaves its effects with us are so slight as to be negligible, and on fruits it has little effect, as it appears to be confined to those which have been injured by codlin-moth or damaged during picking or packing. During the recent fire-blight campaign in the Auckland district many hundreds of cankers were forwarded to the Biological Laboratory, and in nearly every instance these were found to be caused by fire-blight, black-rot, or diplodia-canker. In most cases it was found that the source of infection of black-rot was through some bark-injury, such as is caused by branches rubbing together or abrasions caused by woolly-aphis.

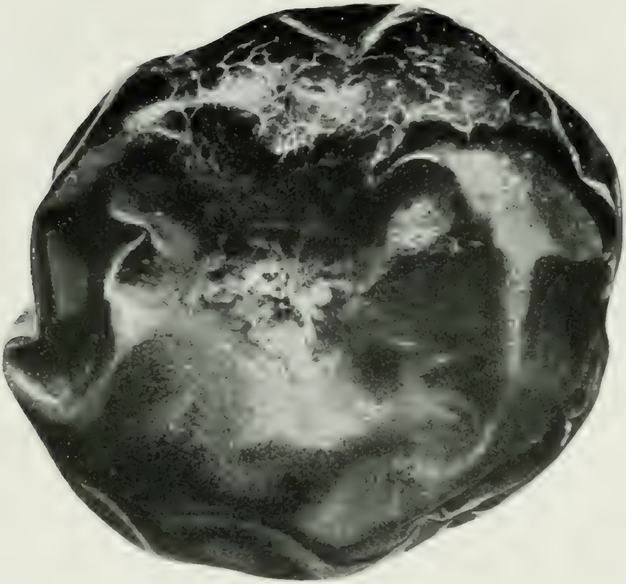

Fig. 32. DUNN'S FAVORITE APPLE INFECTED WITH BLACK-ROT.
Natural size.

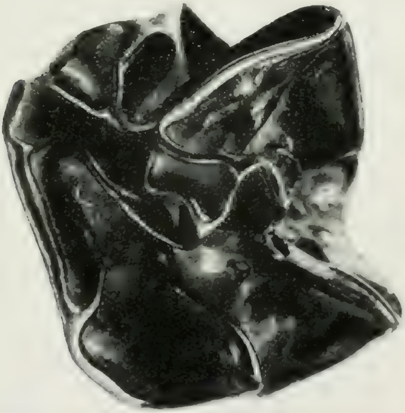

Fig. 33. OLDER CONDITION OF THE ABOVE; TYPICAL MUMMIED CONDITION.
Natural size.

Photos by Author.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Black-rot is caused by *Physalospora Cydoniae,*[*] a fungus having two spore stages in its life-cycle. The first or pycnidial stage, commonly known as *Sphaeropsis Malorum,* is the parasite, the second or ascomycetous stage being saprophytic, as it appears in the dead bark of old cankers. In North America this stage appears to be rare, but in New Zealand it is quite common in cankers that are more than two years old. This fungus is a wound parasite, for it is apparently able to infect fruits and branches only through some injury of the epidermis or bark; but under certain conditions it is a true parasite, for in America it has frequently been demonstrated, by experiments in which conidia have been sprayed on to leaves, that the hyphae of the fungus are able to penetrate directly through the epidermis into the underlying tissues.

Spores discharged in the early spring from fructifications embedded in the dead bark of cankers and the epidermis of mummied fruits are carried by wind or other agency to leaves and injured surfaces of branches, where if moisture conditions are suitable each germinates and produces an infection hypha. This penetrates into the tissues and there branches repeatedly, the hyphae growing between the cells and absorbing from them the food substances necessary for their continued existence. As a result, the host cells are killed, and turn brown. At this stage the hyphae are colourless, but after a time they become dark-coloured, and it is these black masses of hyphae that give the characteristic colour to infected fruits. After a time masses of hyphae immediately beneath the dead epidermis become aggregated into little knots, which eventually develop into spore-bearing receptacles or pycnidia. These are flask-shaped or globose (Fig. 34), and contain numerous one-celled olive-coloured conidia (Fig. 34, *d.*), which are borne on slender conidiophores (Fig. 34, c), produced from the inner surfaces of the lower portion of the pycnidia. The apices of the pycnidia at maturity pierce the epidermis; each is perforated by a small ostiolum through which the spores escape. The spores are

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[*] Doubts have been expressed in mycological literature as to the proper name that should be applied to this species. For Shear *(278; 279)* claimed that ascospores of *Melanops Quercuum* Rehm. forma *Vitis* Sacc. produced in pure cultures pycnidia and spores morphologically identical with *Sphaeropsis Malorum,* whereas Hesler *(160),* after carrying out similar experiments with ascospores of *Physalospora Cydoniae,* also obtained *Sphaeropsis Malorum.* Hesler was able to infect apple-branches with ascospore material and produce typical black-rot cankers. On account of this, and the fact that the New Zealand ascigerous material agrees closely with his descriptions and figures, the name he used has been adopted. Our species obviously belongs to the Pleosporaceae and not to the Melogrammataceae, so that Shear's claim would appear to be untenable in so far as the New Zealand organism is concerned.

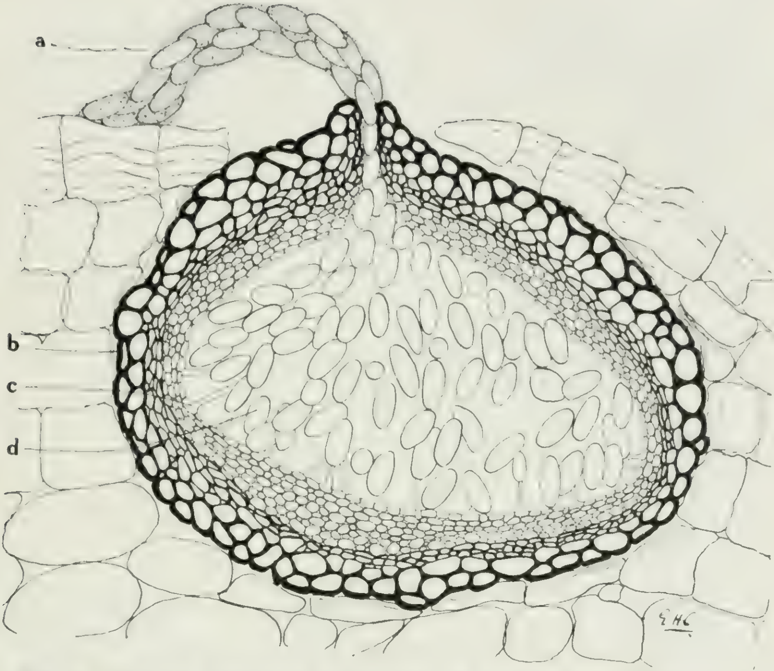

Fig. 34. SECTION THROUGH PYCNIDIUM OF PHYSALOSPORA CYDONIAE (not quite median). × 300.

a. Spore tendril; *b.* wall of pycnidium; *c.* conidiophore; *d.* conidia.

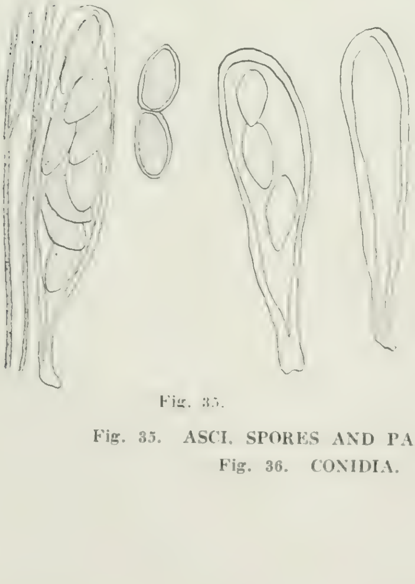

Fig. 35.

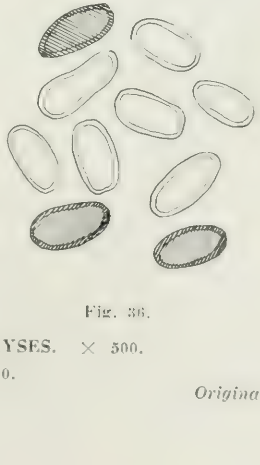

Fig. 36.

Fig. 35. ASCI, SPORES AND PARAPHYSES. × 500.

Fig. 36. CONIDIA. × 500.

Original.

embedded in mucilage, and as this readily absorbs moisture, the spores are forced out through the opening by the swelling of the mucilage, when they appear on the surface in olive-coloured tendrils. The mucilage is dissolved by rain, and the spores released, when they may be washed by rain on to lower leaves and branches, or else carried by wind and insects to adjoining trees.

If a canker lives for more than one season, and the killed bark persists, the second or ascigerous form may appear. This consists of a flask-shaped perithecium containing numerous asci in which colourless one-celled spores are borne (Fig. 35).

These spores may be discharged on to the surface and carried to adjacent trees, where they are probably able to infect leaves and branches, and produce hyphae, which in turn give rise to pycnidia. Conidia are apparently able to remain viable for a considerable time, for in the laboratory the author has been able to infect apple-fruits with conidia taken from pear-cankers which have been kept in the herbarium for over twelve months.

REMEDIAL TREATMENT.

As the mycelium of this fungus may remain alive in a canker for several seasons, and during the growing-period is capable of producing fructifications (pycnidia) bearing spores, it would appear that these cankers are the means by which the fungus is able to carry over from season to season. This is borne out by American experience, for there it has been observed that early in the season, in the vicinity of viable cankers, leaf-infection commences shortly after the leaves emerge from the buds. Furthermore, American workers have recorded the fact that infection may commence from mummied black-rot fruits remaining on the trees, for they frequently have observed leaf-infection to commence in the vicinity of these fruits. On spots on living leaves spore-production is so uncommon that it is probable leaf-infection occurs throughout the season from spores produced from pycnidia in cankers and mummied fruits. Fructifications are commonly produced on leaves that have fallen to the ground, so fallen leaves that have escaped desiccation during the winter months are in all probability a source of infection the following spring.

Doubtless in New Zealand black-rot is held in check somewhat by spray treatment, but not entirely, for it appears to be about equally common in sprayed and unsprayed orchards. Such being the case, the eradication of the sources of infection would appear to be the only effective treatment that can be recommended. These sources are *(a)* cankers on the branches, *(b)* mummied fruits remaining on the trees and lying on the surface of the ground, and probably (*c*) infected leaves which have escaped desiccation during the winter months. The following treatment is therefore suggested:—

(1) Cut out cankered branches, cutting some 7 cm. (3in.) below the visible point of infection.

(2) Remove and destroy any black-rot mummies lying on the ground or hanging on the trees.

(3) Plough in late autumn, after the leaves have fallen, and with a spade turn under beneath trees portions which have been left untouched by the plough.

The author does not suggest that any treatment of cankers be practised, for at best this is difficult and involves a great amount of work; furthermore, as the hyphae of the fungus spread in the sap-wood some distance beyond the visible point of infection, control at best would be uncertain. As many wounds are caused by branches rubbing together, trees should be pruned in such a manner as to prevent this. Finally, all wounded surfaces should, as soon as made, be coated with coal tar.

SUMMARY.

1. Black-rot forms cankers on the branches, spots on the leaves, and causes rotting of fruits.

2. In New Zealand it is confined to the apple, pear, and quince, but in North America has been recorded on numerous other hosts.

3. On branches and fruits it behaves as a wound parasite, as it is apparently able to infect these only through some abrasion in the bark or epidermis; on leaves it behaves as a true parasite, infecting them directly through the epidermis.

4. Black-rot is caused by the fungus *Physalospora Cydoniae*.

5. It overwinters by means of resting mycelium in cankers and mummied fruits, and probably in fallen leaves.

6. Remedial treatment consists in the removal of the sources of infection.

For literature references dealing with this disease, see bibliography, p. 349, numbers *27, 60, 121, 160, 161, 188, 202, 276, 278, 279.*

CHAPTER XIV.

POME-FRUIT DISEASES.

(Continued.)

(a) Fungous Diseases.—Continued.

BLACK-SPOT, Venturia inaequalis (Cke.) Aderhold *(21)*.

Syn.: *Sphaerella inaequalis* Cke.; *Venturia Pomi* (Fr.) Wint.; *Venturia inaequalis* (Cke.) Wint.; *Fusicladium dendriticum* Fcl.

Apple-scab.

Except in favoured localities where the humidity is low during the growing season, such as in Central Otago and certain localities in Marlborough and North Auckland, black-spot is common on apples throughout New Zealand. It occurs also in Europe, North America, South Africa and Australia.

The conidial or summer stage appears in the form of dark-coloured spots on the leaves, fruits and shoots. The ascigerous or winter stage occurs as a saprophyte, the perithecia developing in the spring from mycelium which has overwintered in dead leaves. This stage does not occur on fruits or shoots, being found only in the tissues of the dead leaves.

The conidial stage was first recorded for New Zealand by Kirk *(177)* in 1894; the ascigerous stage by Miss Curtis *(125)* and the author *(108)* in 1921.

Black-spot is not confined to the cultivated apple *(Pirus Malus)*, since in Europe *(23)* and North America it has been recorded on related species of the genus *Pirus*. For example, in North America it occurs on the wild crab *(Pirus coronaria)*. It is unable to infect hawthorn or pear, a similar disease of these hosts being caused by related species.

APPEARANCE AND EFFECT ON THE HOST.

Black-spot makes its appearance on the leaves about the first week in November, the exact time varying with the blossoming-period of the host variety (Fig. 37). It is not generally observed at this early stage, owing to the spots being small, scattered, and situated chiefly on the under-surface of the leaf. Their occurrence

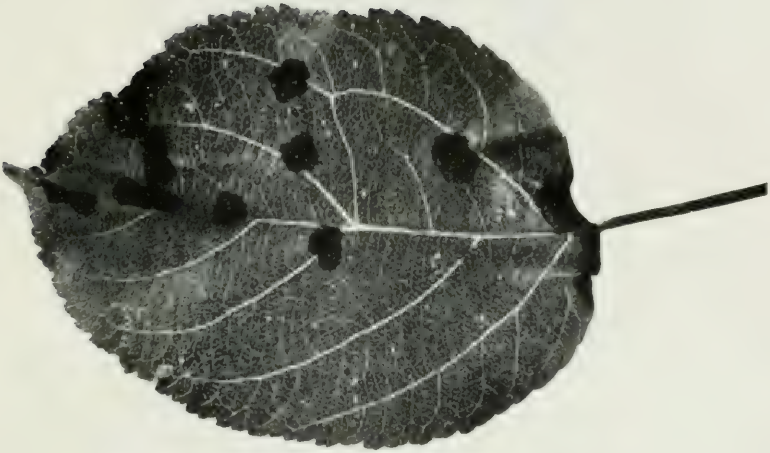

Fig. 37. BLACK-SPOT LEAF INFECTION. Natural size. Docherty leaf with lesions on the upper surface.

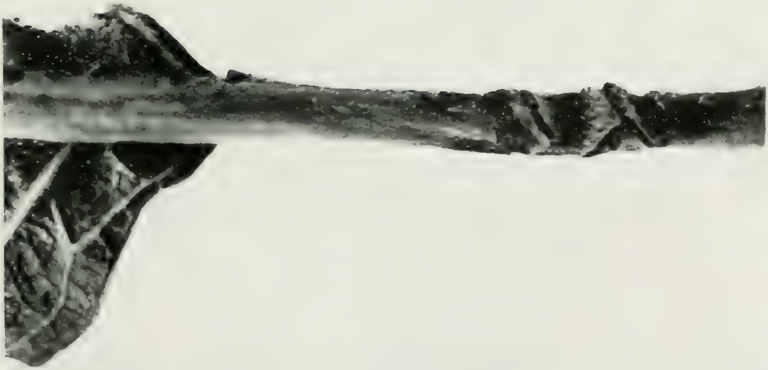

Fig. 38. BLACK-SPOT PETIOLE INFECTION, SHOWING SMALL CANKERS WHICH CAUSE PREMATURE LEAF-FALL. × 4.

Photos, E. Bruce Levy.

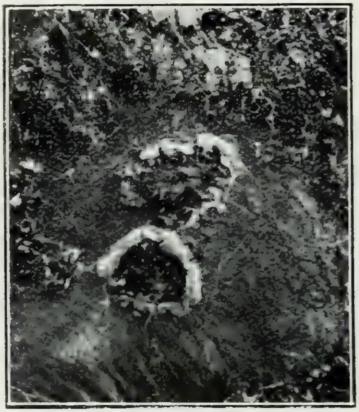

Fig. 39. BLACK-SPOT FRUIT INFECTION: LESIONS SURROUNDED BY THE UPRAISED CUTICLE. × 10.

Photo, E. Bruce Levy.

in this position is due to the fact of the under-surface being first exposed as the leaf emerges from the bud. The spots are olivaceous, and have at first a somewhat indefinite outline, owing to the hyphae of the fungus radiating outwards from the source of infection. Though few at first, they may later increase in numbers, until the whole leaf-surface becomes covered with small spots, which grow until their margins meet, so that ultimately nearly the whole surface may be involved. Sometimes the portion of the leaf-tissue below these spots becomes upraised and presents a bullate or blistered appearance, the other surface becoming correspondingly depressed or concave. The spots on the lower surface are usually more irregular in outline than those of the upper surface, and tend to follow the direction of the main veins. The leaf-tissues under the centre of the old spots are often killed outright, when they assume a brown colour and occasionally fall away, leaving perforations in the leaf. Infected leaves frequently become incurved or distorted, generally remain smaller in size, and usually fall prematurely, so that in a season when black-spot is prevalent the trees may become completely defoliated. On the petioles small cankered areas are formed which cause the death of infected tissues, followed by premature leaf-fall (Fig. 38).

Black-spot first appears on fruits shortly after they have set, when it shows on the calyx and pedicels, and has been recorded on petals, anthers and pistils *(290)*. When pedicels are infected, the young fruits as a rule fall off, their further development and nutrition being prevented by the hyphae of the fungus. When spots appear on the calyx distortion of the fruit usually follows, the parasitised cells being damaged to such an extent that they are unable

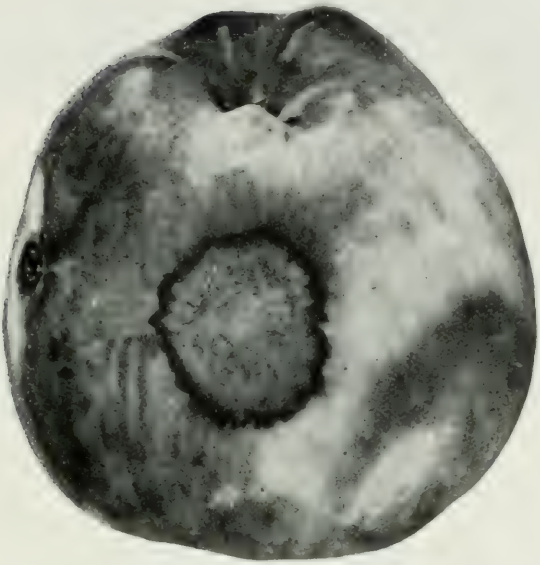

Fig. 40. EARLY INFECTION ON DELICIOUS APPLE. Natural size. Note the large size of the spot and the russeted central area.

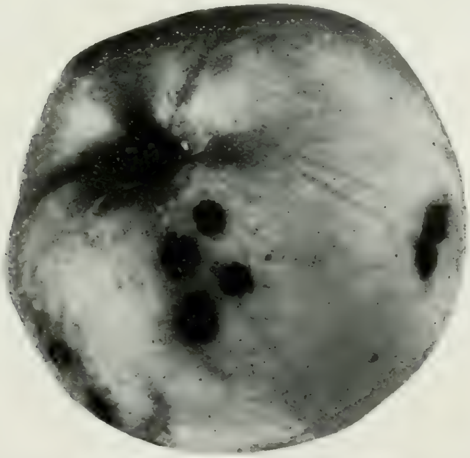

Fig. 41. LATE INFECTION ON DOCHERTY APPLE. Natural size. Note the small size of the lesions.

Photos, E. Bruce Levy.

to develop further, and as growth continues in the cells in their vicinity, misshapen fruits result. Such distorted fruits commonly fall, as owing to unequal growth they come into contact with other developing fruits, and are forced from the spur to which they are attached. On maturing fruits the spots appear as olivaceous, more or less circular areas, surrounded by greyish edges formed from the marginal portion of the undissolved part of the cuticle, which has been forced apart from the epidermal cells by the invading hyphae (Fig. 39). Fruit-infection usually occurs at the calyx end, as this is the area most exposed to moisture and the wind-borne spores. After infection the spots continue to enlarge in a circular manner; then after a time their centres usually become exposed, as the spores are carried away by wind or rain, when they appear as brownish russeted areas (Fig. 40). On actively developing fruits the spots become depressed or sunken (Fig. 40). This is due to the fact that immediately beneath the spots corky tissue is formed, which is hard and unyielding, growth of the host tissues being thus prevented in this region, while the surrounding healthy tissues continue their development beyond it. These spots may coalesce, and after the spores have disappeared the internal pressure of the developing host cells often causes the formation of large cracks, which afford opportunity for the entry of the spores of fruit-rotting fungi.

When late infection occurs on mature or nearly mature fruits the spots are as a rule minute, and the fruits do not show any depressed areas or russet-marks (Fig. 41). Black-spot development may continue in cool-store, spots in this case presenting large greyish borders surrounding intensely black centres (Fig. 39). The intense colouration is due to the masses of dark-coloured spores, which in the still atmosphere of a cool-store are not carried away, but remain where they are formed.

Shoot-infection varies somewhat in appearance according to the host variety attacked. On certain varieties the epidermis of young shoots may be studded with light-brown spots consisting of blister-like pustules containing conidia in their centres (Fig. 42). In other varieties infected shoots are somewhat swollen and blistered, the bark ultimately peeling off in flakes; or lesions resembling those on fruits may be formed (Fig. 43). Vigorously growing shoots and water-shoots appear to be more readily attacked. These lesions tend greatly to weaken the shoots and render them liable to fracture; moreover, they facilitate the attacks of diplodia-canker, black-rot, and other canker-forming fungi.

ECONOMIC IMPORTANCE.

Black-spot is the most serious apple-disease with which the orchardist has to contend, as it not only weakens the tree by damaging the leaves, but reduces the market value of the fruit

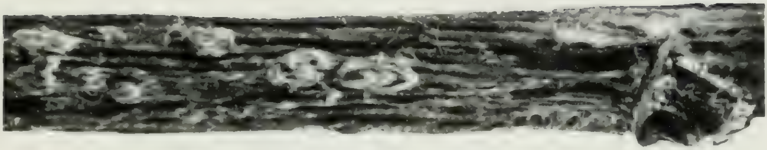

Fig. 42. APPLE-SHOOT INFECTION. × 4.
Pustules on Docherty lateral.

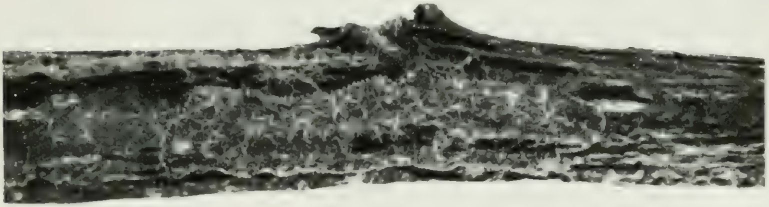

Fig. 43. APPLE-SHOOT INFECTION. × 4.
Lesions on wood similar to those formed on fruits. Dotted outline shows size of the lesion.

Photos, E. Bruce Levy.

through the development of disfiguring spots, scabs, and cracks on the epidermis. In cases of severe infection the crop may become a total loss, owing to the developing fruits being so damaged as to fall to the ground at the time of setting or shortly after. As a result of fruit-infection loss may be caused in four ways:—(1) The fruits may fail to set owing to their being killed outright by the fungus; (2) young fruits may fall to the ground; (3) fruits may become distorted, badly scabbed, or cracked, and thus be rendered unsaleable; (4) the quality of the fruit and its keeping properties may become impaired by the development of disfiguring marks on the surface.

In the last case the disease does not result in the rotting or breaking-down of the tissues of the apple, as is the case with bitter-rot and other similar fruit-rotting fungi. On the contrary, the most noticeable effect may be a mere superficial disfigurement of otherwise mature and healthy fruit; nevertheless, this defect in quality is often enough in itself to render a large portion of a crop unsaleable. Serious as this may be, it is by no means the worst feature of black-spot; in several ways it may directly reduce the quantity of fruit. This aspect of the disease is more liable to pass unnoticed, but it is immeasurably more disastrous in its results. Black-spot thus affects the quantity as well as the quality of the output—the two factors on which the profit of the orchardist depends.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Black-spot is caused by the fungus *Venturia inaequalis.* The conidial stage, long known as *Fusicladium dendriticum,* is the active agent, the ascigerous stage being merely saprophytic, occurring on dead leaves. Nevertheless, it is mainly this saprophytic stage that spreads the disease afresh each season.

In early November black spots begin to appear on leaves and developing fruits, arising as a result of infection either from ascospores produced from perithecia formed in dead leaves or from conidia produced from stromata which have overwintered on shoots.

If a spore (ascospore or conidium) alights on a leaf or fruit surface, and conditions prove favourable, it germinates and produces an infection-hypha, which penetrates the cuticle, beneath which it branches repeatedly to form a mycelium, which derives its nourishment from the solution of the cuticle and from cells of the epidermis or parenchyma lying immediately beneath. About a fortnight after infection this mycelium develops a stroma consisting of closely woven masses of hyphae (Fig. 44, *st*); from it upright conidiophores are produced, arranged in closely packed columnar masses (Fig. 44, *con*); on their apices the olive-coloured, elliptical conidia are produced (Fig 44, *sp*), being cut off in succession from the conidiophores. During the development of the stromata and conidiophores the cuticle is gradually forced away from the epidermis, and at this stage appears as a greyish border surrounding the spore masses (Fig. 39). The conidia are readily detached, and being light are carried by wind or other agency to neighbouring leaves or fruits, which in turn may become infected. Conidia remain viable for but a short time, so that subsequent infection must occur from conidia produced throughout the season from stromata on leaves, fruits, or shoots.

Infected leaves sooner or later fall to the ground, where they become permeated with the dark-coloured mycelium. In the autumn perithecia begin to form from this mycelium, but do not reach maturity until after the winter months, their development being completed in August and September. A perithecium is a flask-shaped receptacle, the walls of which are formed of closely woven hyphae (Fig. 45). In its early stages it is filled with hyphal filaments, certain of which later develop into asci (Fig. 45, *a*), each containing eight two-celled ascospores. The ascospores at first are colourless and unicellular, but at maturity they become unequally septate and yellowish-green (Fig. 46, *as*). During development the perithecium is completely buried within the leaf, but as it reaches maturity it approaches the leaf-surface until the neck, which is perforated with a minute ostiolum (Fig. 45, *os*), pierces the epidermis and opens on to the free surface (usually the lower) of the

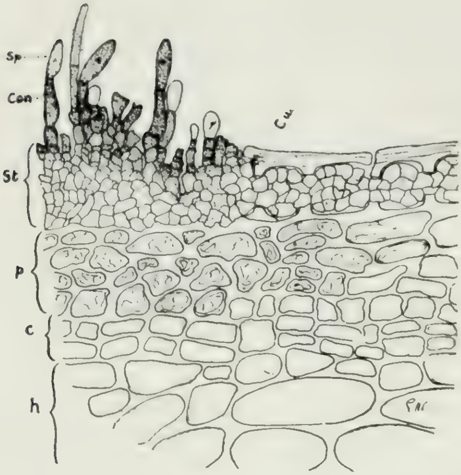

Fig. 44 SECTION THROUGH LESION ON FRUIT. × 180.
c. "Cambium"; *con.* conidiophores; *cu.* cuticle: *h.* healthy parenchyma; *p.* plasmolysed cells affected by the fungus, brown in colour; *sp.* conidia; *st.* stroma formed of closely woven hyphae.

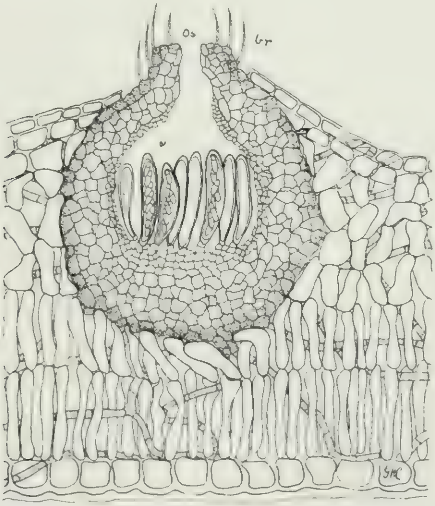

Fig. 45. SECTION THROUGH A DEAD LEAF CONTAINING A PERITHECIUM OPENING ON TO THE LOWER SURFACE. × 170.
a. Asci; *br.* bristles; *os.* ostiolum.

Original.

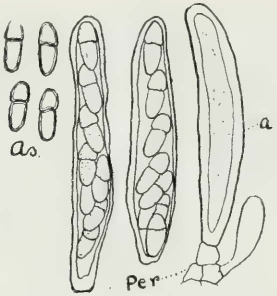

Fig. 46. ASCI AND PARAPHYSES. × 400.
a. Asci; *as.* ascospores; *per.* portion of perithecium to which the asci are attached.
Original.

leaf. As the perithecium matures, the neck, which at first is smooth, becomes crowned with a few coarse black bristles (Fig. 45, *br*). Perithecia, as a rule, develop only on leaves that have been somewhat protected during the winter months; leaves found under hedges, clods, etc., contain numerous perithecia, while those lying exposed on wet ground have few or none. From September until December, on the occurrence of rainy weather, the ascospores are discharged from the perithecia into the air, being ejected sufficiently high to be caught in and carried by air-currents to developing leaves and fruits in the neighbourhood. The discharge of ascospores is dependent on the presence of abundant moisture, which causes certain portions of the asci and perithecia to swell to such an extent that the enclosed asci are subjected to considerable pressure, thus forcing out their contained ascospores through the perithecia into the air. So great is the pressure developed by the swelling of these hygroscopic portions that the entire perithecium sometimes is shattered, asci and spores being ejected into the air with considerable force, the embedded base of the perithecium alone remaining in the leaf-tissues. Not only is abundant moisture essential for the discharge of the ascospores, but it must also be present on the leaves before an ascospore can germinate or its infection hypha pierce the cuticle.

When an ascospore germinates, it produces an infection hypha (usually two are produced, one from each cell), which penetrates the cuticle, beneath which it branches repeatedly, giving rise to a stroma on which conidia are produced. The production of conidia thus completes the cycle.

The fungus may overwinter on infected shoots, when in spring it produces conidia capable of causing leaf, fruit, and shoot infection as soon as leaves appear.

CONSIDERATIONS REGARDING CONTROL.

From the foregoing it becomes apparent that black-spot is carried over the winter by mycelium embedded in the dead leaves and by mycelium overwintering in infected shoots. We have seen that from this mycelium in the dead leaves perithecia containing ascospores are developed in the spring. We know that these ascospores which are discharged some time prior to, during, and for a short time after blossoming, are one of the sources of primary infection, and that when they infect leaves or fruits they give rise to mycelium from which conidia are produced, these conidia in turn causing infection throughout the season. Furthermore, we have seen that from mycelium embedded in infected shoots are produced conidia which are capable of producing the disease as soon as the leaves and fruits appear.

Thus it would appear that in order to enable the control of the disease to be carried out we must either *(a)* prevent primary infection by the destruction of leaves containing perithecia, and deal with shoot-infection in such a manner that formation of conidia is prevented, or *(b)* prevent ascospore and conidial infection by covering developing foliage and fruits with a protective spray.

(a.) If the fungus were perpetuated by ascospores alone, then the destruction of all leaves containing perithecia would prevent primary infection, clean fruit would result, and spraying would be unnecessary. Unfortunately, this would be impossible in orchard practice, as leaves containing large numbers of perithecia commonly occur in such places as under hedges, etc., where they cannot be buried by the plough. Destruction of fallen leaves by hand has been recommended *(126)*, but this is impracticable, owing to the time that this would take and the labour that would be required. Doubtless, infection is minimised by the destruction of a large proportion of the leaves, so that where possible cultural operations should be carried out before ascospore discharge begins in the spring—that is, before September.

Even if the destruction of fallen leaves were practised, infection would still be liable to occur from the conidia developed on infected shoots. The cutting-out of these would not be entirely satisfactory, as this treatment would require a modification of the present lateral system of pruning, and would, moreover, necessitate the examination of every shoot, an operation which would be impracticable in a commercial orchard during pruning operations.

(b.) If ascospore discharge occurred during a short period only, then a single spray application at this time would be all that was necessary to combat this phase of black-spot infection. Unfortunately, spore-discharge occurs over a period of weeks, beginning some time before blossoming and continuing for some time after. Infection does not cease with the completion of ascospore-discharge.

but continues throughout the whole of the growing-period and afterwards, occurring even in cool-store. Throughout the season conidia are being produced on leaves and fruits, and it is these that cause late infection, as they may be carried by air-currents for long distances. Thus, even an orchard that has been sprayed thoroughly during the blossoming-period is subject to infection from these wind-borne conidia. Spray applications, therefore, are necessary throughout the season to prevent infection. When fruit is to be placed in cool-store a spray application before picking will be of value in preventing infection while in the store.

To summarise: A series of spray applictaions is necessary, so that the danger period of ascospore infection may effectively be covered, conidia on shoots destroyed. and subsequent development of conidia on leaves and fruits prevented.

CONTROL.

It has been shown that control of black-spot by destruction of infected leaves is impracticable, not only because of the difficulty of destroying all the leaves, but because the danger of infection from diseased shoots still remains. Nevertheless, as destruction of infected leaves would tend to minimise infection by reducing the number of ascospores, it should be practised wherever feasible. It would therefore be advisable to plough deeply in the autumn and dig under all portions left by the plough, thus burying as many leaves as possible.

Spray according to the schedule on p. 85, which has given complete control when the times of application and quantities of materials have been adhered to.

SUMMARY.

1. Black-spot is a fungous disease attacking the leaves, shoots and fruits of the apple; forming on leaves and fruits dark-coloured irregular spots, and on the shoots small elliptical cankers.

2. The causal organism is *Venturia inaequalis,* a fungus possessing two spore-stages in its life-cycle: the first or conidial stage is the parasitic one, the second or ascigerous stage being saprophytic, for it is found only in dead leaves which have survived desiccation through the winter months.

3. The organism overwinters by means of resting mycelium in fallen leaves and living shoots.

4. The disease may be controlled by spraying alone, but it is advisable to supplement spray treatment by ploughing under fallen leaves prior to blossoming, and thus reduce the danger of ascospore infection.

For literature references dealing with this disease, see bibliography, p. 349, Nos. *21, 22, 23, 102, 108, 114, 125, 126, 127, 177, 225, 290.*

BLISTER-DISEASE, Coniothecium chomatosporum Corda *(104b)*.

Syn.: Apple branch-blister; apple-cracking; coniothecium-blister.

This disease, although commonly overlooked by the orchardist, is prevalent throughout the orchard areas of New Zealand. It occurs on the fruit and laterals of the apple and pear. Although prevalent in New Zealand, it appears to have a limited distribution elsewhere, for it has been recorded only from England, Europe, and South Africa. It is common on certain varieties, notably Scarlet Nonpareil, Cox's Orange Pippin, Irish Peach, Rome Beauty, and Docherty. The disease was first recorded for New Zealand by Kirk *(188)* in 1907.

APPEARANCE AND EFFECT ON THE HOST.

On laterals it is abundant on one and two-year-old wood, but it appears to be scarce on branches older than this. On these laterals it appears in the form of small, olive-coloured, irregularly-shaped blisters, which stand above the surface of the bark about 1 mm. (Fig. 47). These blisters may occur singly, scattered over the surface of the bark, when they attain a diameter of about 2 mm., or may be aggregated into groups forming large and irregular areas, which may attain to a length of several cm. Generally they have an unbroken surface, but on older wood the blisters not uncommonly crack across, giving to the bark a rough and scabbed appearance. When the blisters are scattered their presence is difficult to detect, but when confluent they are quite conspicuous.

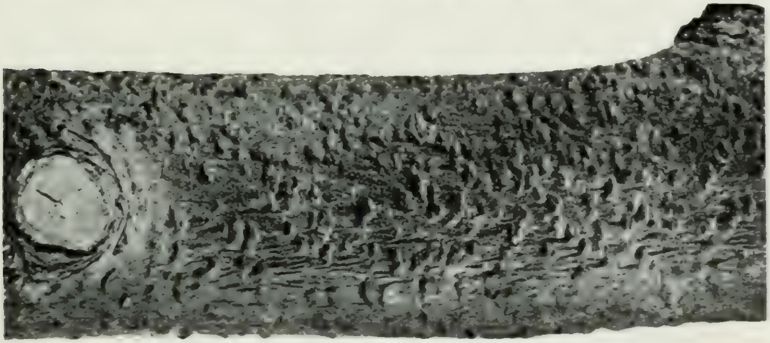

Fig 47. BLISTER-DISEASE ON APPLE BRANCH. Natural size. These blisters are characteristic of this disease on wood.
Photo. H. Drake.

For explanation of terms, see glossary, p. xi.

On fruits a russeted condition is produced, but, if infected when young, large unsightly cracks may be formed. These may be seen especially on the stem end of the variety Cox's Orange (Fig. 48). These cracks are usually large, crescentic, and possess rounded edges (Fig. 49). They are quite rough to the touch, and frequently possess an olivaceous appearance due to the presence of the fructifications of the causal organism. The disease is not known to occur on leaves.

ECONOMIC IMPORTANCE.

On laterals and branches the culminative effect of this disease is a stunting of the tree, for one invariably finds that severely infected trees are below the normal in size. On individual branches the effect is negligible, save where confluent blisters are formed, for then the bark is roughened, and the areas thus formed serve as points of entry for other canker-forming fungi.

It has been claimed for this disease that it kills the tissues of the cortex down to the wood, and that as a result the branch dies *(208)*. In England this may be so, but such a condition is not known to occur in New Zealand, for although the author has had this disease under observation for five years, he has never found it do more than form the blisters described above.

On fruits the effects are more serious, for in cases of late infection a russeting occurs which tends to lessen the market value of the fruit; and where early infection has taken place the large cracks formed so malform the fruits as to make them worthless, save for factory purposes. Further, these cracks serve as points of entry for fruit-rotting organisms, so that many infected fruits never reach the market since they are decayed ere they are packed. Should such scabbed fruits be placed in cool-store, they invariably succumb to storage rots, as these blister-disease scabs are among the principal points of entry for this type of organism.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Two spore stages are present in the cycle of this organism—the first or *Coniothecium* stage being parasitic, the second stage, apparently saprophytic, occurring on dead bark of old scabbed areas, etc. Until recently, only the *Coniothecium* stage was known, but cultural work by Massee *(208)* and Van der Bijl *(308)* has definitely linked this with a species of *Phoma* which the former worker considered to be *Phoma Mali* Schulz et. Sacc.

Massee found *Phoma* pycnidia on branches associated with *Coniothecium*, and in addition once found an ascomycete which he determined as *Diaporthe ambiguua* Nits. Because of its association with these other spore forms, he came to the conclusion that *Coniothecium chomatosporum* and *Phoma Mali* were but forms of *Diaporthe ambiguua*. I also have

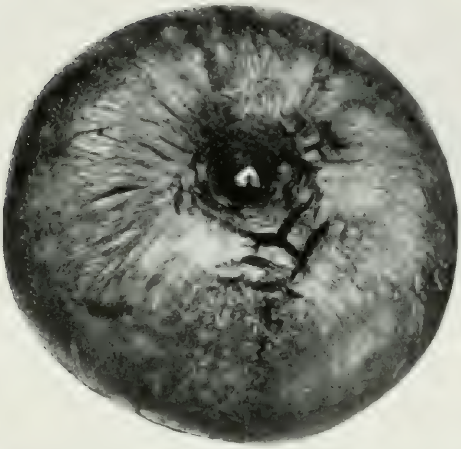

Fig. 18. BLISTER-DISEASE ON APPLE FRUIT (Cox's Orange Pippin). × $\frac{2}{3}$.
The usual condition following early infection.

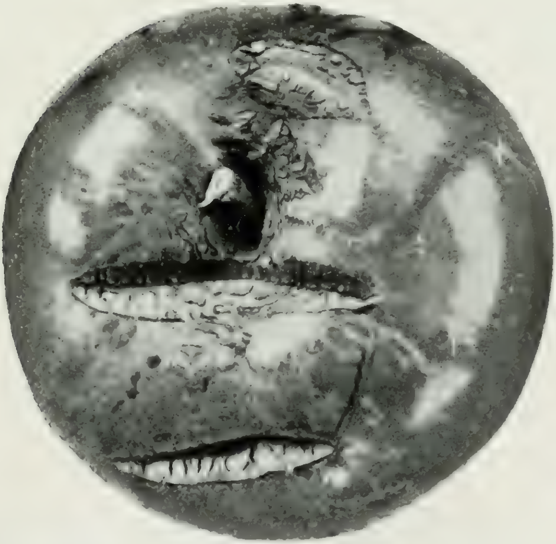

Fig. 19. BLISTER-DISEASE ON APPLE FRUIT (Dunn's Favorite). × $\frac{2}{3}$.

Photos. H. Drake.

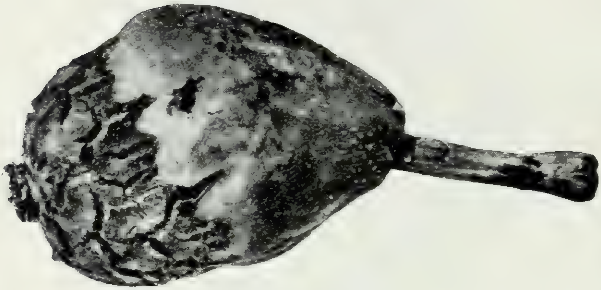

Fig. 50. BLISTER-DISEASE ON IMMATURE PEAR FRUIT. × ½.

Photo, E. Bruce Levy.

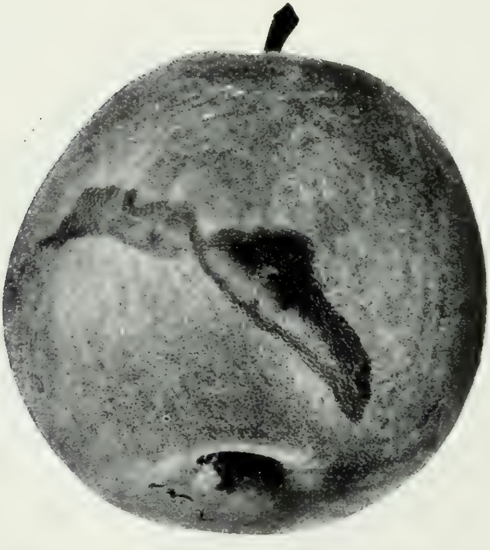

Fig. 51. BLISTER-DISEASE ON MATURE PEAR FRUIT. Natural size.

This condition results from late infection; a soft rot is produced, and in the tissues both stages of the fungus may be obtained in abundance.

Photo, H. Drake.

obtained abundant *Phoma* pycnidia in culture, but neither Van der Bijl nor myself has found *Diaporthe*. The *Phoma* stage agrees closely with the description of *P. Mali* Schulz. et Sacc., and I would so refer the species were it not for the fact that the matter is further complicated in that Diedicke *(130)* has published a statement to the effect that *Phoma Mali* is in reality *Phomopsis Mali* (S. et S.) Died. Now *Phomopsis Mali* is preoccupied, for this name was the previous year applied by Roberts *(259 bis.)*, who mentioned that his organism from leaves may easily be mistaken for *Phoma Mali* Schulz. et Sacc., but from apple wood and fruit was characteristically a species of *Phomopsis*. The "rough-bark" condition described by Roberts as being caused by this organism does not in any way agree with the condition caused by *Coniothecium* in New Zealand. Further, Roberts makes no mention of a *Coniothecium* stage being found in his cultures.

More recently we find that Kidd and Beaumont *(176 bis)*, as a result of the examination of cultures, consider that *Phomopsis Mali* Roberts is a conidial stage in the cycle of the ascigerous fungus *Diaporthe perniciosa* E. et E. March. As I have been unable to ascertain (through lack of time and cultural material) whether the New Zealand organism is *Phoma Mali* Schulz. et Sacc., "*Phomopsis Mali*" (S. et S.) Died. (a name which is untenable), or *Diaporthe perniciosa* E. et E. March., I have been compelled to use for the organism causing blister-disease the original name, ***Coniothecium chomatosporum*** **Cda.**

The fungus overwinters on shoots either in the form of pycnidia, or in the tissues in mycelial form (*Coniothecium* stage), and may be spread by either one of the two following methods:—

(a) In the spring conidia are extruded from pycnidia and carried by wind or other agency to adjacent shoots, where, should conditions prove favourable, they germinate and produce slender infection-hyphae. These penetrate through lenticels *(208)* and form a mycelium of delicate hyaline hyphae, which penetrate to the living cells of the cortex. Here they enter between the cells,

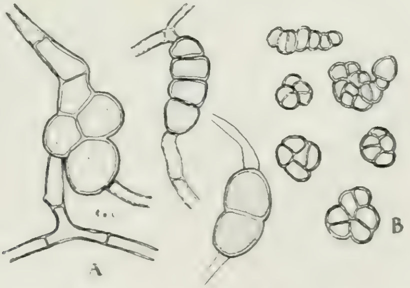

Fig. 52. CONIDIA AND CHLAMYDOSPORES OF CONIOTHECIUM CHOMATOSPORUM. × 500.

A. Chlamydospores from cultures; B. "conidia" from the cortex of an apple shoot. *Original.*

penetrating the middle lamella *(307)*, where they increase in thickness, assume an olive-green colour, and eventually give rise to short, multicellular, thick-walled chlamydospores. These become aggregated into small packets (Fig. 52), forming the *Coniothecium* stage of the organism.

(b) The chlamydospores may produce hyphae which grow slowly between the cells. These hyphae grow between the cells of the new growth, giving rise to the blistered condition so noticeable on infected shoots. According to Massee *(208)*, the spores of the *Coniothecium* stage, if exposed to the air by rupture of the covering cortex, may in turn produce colourless, minute buds, which, if detached and carried to adjoining branches, may produce hyphae which penetrate to living tissues in a manner similar to that described for the conidia.

The blisters are formed by the mycelium penetrating between the host cells, causing them to separate, and forcing them upwards and outwards. On young fruits the fungus damages the "cambium" layer, which at this stage is but a few cells below the surface; consequently, as growth is prevented in this region, cracks are formed through the growth of the surrounding uninfected tissue. On older fruits the russeting is produced by the fungus uplifting the cuticle and epidermis; consequently the exposed cells die, and beneath them is formed a corky layer which gives to these areas their characteristic russeted appearance.

REMEDIAL TREATMENT.

As the mycelium is embedded in the tissues of the host, it follows that spray treatment will have little effect upon the organism. But spraying is of benefit in that it would prevent infection of shoots and fruits from wind or rain-borne conidia and buds. As severely infected trees are invariably stunted, and consequently bear little fruit, it would be advisable to prune heavily all such trees, cutting away the majority of laterals and fruit spurs. By this treatment vigorous growth would be induced, and, what is more to the point, the sources of infection would be removed. It would be impracticable in pruning operations to look for infected shoots, for unless confluent blisters were present, these would be readily overlooked, but by sacrificing the fruit from stunted trees for a season the drastic pruning of all laterals would remove all infected material. It would be advisable then to spray the trees at green-tip with bordeaux 5-4-50, and follow up with the usual summer applications.

SUMMARY.

1. Blister-disease is a fungous disease attacking laterals, branches and fruits of the apple and pear, and so far as is known is confined to these two hosts.

2. It forms olivaceous blisters on the laterals, and russets and cracks the fruits, the cracks being more prevalent near the stem end of the fruit.

3. The causal organism possesses a *Coniothecium* stage in its life-cycle which has been linked up by the aid of cultures with a species of *Phoma*.

4. The organism overwinters on infected shoots and fruits, and infects developing shoots through the lenticels.

5. Remedial treatment recommended is *(a)* to prune heavily all severely infected trees by cutting away laterals and fruit spurs, thus inducing strong growth and removing sources of infection (a method that has proved successful where tried out); and *(b)* to spray at green-tip with 5-4-50 bordeaux, following with the usual summer applications.

For literature references regarding this disease, see bibliography, p. 349, numbers *130, 188, 208, 307, 308.*

BROWN-ROT, Sclerotinia cinerea Schroeter.

This, a serious disease of stone-fruits in New Zealand, has occasionally been found on apples, pears and quinces. It causes a rot of the fruit, a rot which gradually spreads until the whole fruit becomes infected, when it turns quite black, at this stage resembling in appearance fruit infected with black-rot (p. 121). Few or no tufts of conidia are produced on the surface of infected fruits, although if they are sectioned fructifications soon develop on the exposed flesh. In New Zealand brown-rot of pome-fruits appears to gain entry through some injured portion of the epidermis, such as is caused by codlin-moth, bronze-beetle, or branch rubs.

In Europe a destructive brown-rot of pome-fruits is known. This disease, caused by a related species, *Sclerotinia fructigena* Schroet., fortunately does not occur in New Zealand, although in many of the earlier reports it has been recorded as being present. These records have been due to mis-determination of the causal organism.

(For life-history and control, see under stone fruits, p. 228).

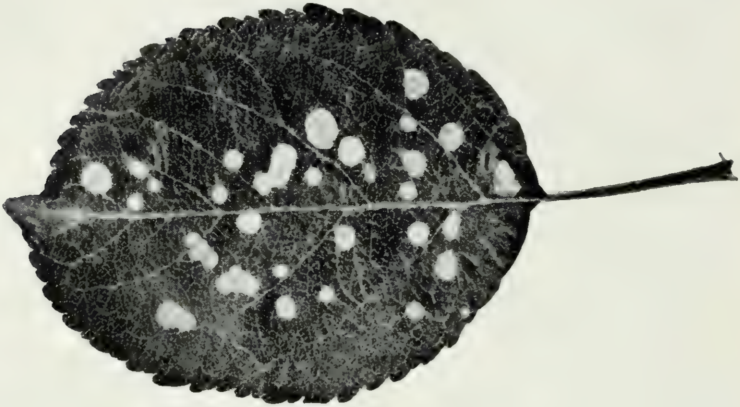

Fig. 53. CIRCULAR-SPOT ON STURMER APPLE LEAF. Natural size.
Photo, E. Bruce Levy.

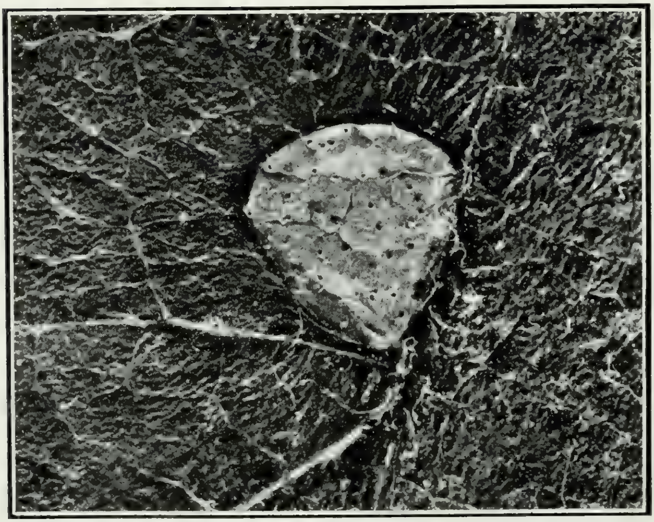

Fig. 54. CIRCULAR-SPOT WITH THE NECKS OF NUMEROUS PYCNIDIA SHOWING. × 10.
Photo, H. Drake.

CIRCULAR-SPOT. Phyllosticta Pirina Saccardo *(267)*.

On apple trees throughout New Zealand during the summer months leaves are frequently found affected with an almost circular, ochraceous spot, visible on both surfaces (Fig. 53). On certain trees, indeed, this condition is so prevalent that scarcely a single unaffected leaf can be found, especially with the varieties Cox's Orange Pippin and Sturmer Pippin. Orchardists frequently attribute this spot to spray injury, but this belief is untenable, for it is found to be equally abundant on sprayed and unsprayed trees.

APPEARANCE AND EFFECT ON THE HOST.

The spots are visible on both leaf surfaces, are invariably circular in outline, save where two or more merge, and are ochraceous or ashy-grey in colour. On the upper surface of the leaf the spot is slightly depressed below the level of the normal leaf tissue, and is sharply bounded by an elevated ridge of rather darker colour (Fig. 54). The spots vary in number from one or two to 100 or more, and when numerous are scattered over the entire leaf surface; in size they range from 2 to 8 mm. or more, or when confluent may attain a length of 15 mm.

In the centre of the spot may usually be seen several scattered black dots, the pycnidia of the causal organism (Fig. 54). Spots are to be found as a rule only on older leaves, and are especially numerous on leaves that are somewhat yellowed. Whether the spots cause this yellowing is unknown, but it is probable that they are a contributory factor on account of their prevalence. These yellow leaves fall prematurely. The spots consist of dead cells, and where at all abundant, detrimentally affect the leaf by reducing the surface area, thus limiting the work of transpiration and photosynthesis.

CAUSAL ORGANISM.

The cause of this condition has been the subject of much discussion, and has not yet been satisfactorily settled, for no innoculation work has been undertaken to determine whether the fungus invariably associated with the spots is parasitic, or whether it merely lives saprophytically upon the dead tissues.

In New Zealand it was at one time attributed to *Alternaria Pirina (187);* and it has been claimed *(92)* that on similar lesions *Septoria Piricola* and *Alternaria* sp. have been found. A somewhat similar condition has been recorded from North America as being caused by *Phyllosticta Pirina* Sacc., but it seems probable that this is a misdetermination, for the fungus, once so known there, is now named *Coniothyrium tirolense* Bubak (= *Coniothyrium Pirinum* (Sacc.) Sheldon), and does not agree morphologically with *Phyllosticta Pirina* of Europe.

The author has invariably found present in these spots a species of *Phyllosticta,* which Dr. Butler[*], Director of the Imperial Bureau of

For explanation of terms, see glossary, p. xi.

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[*] Letter to the author, 11/12/22.

Mycology, Kew, has determined as being *Phyllosticta Pirina* Sacc., basing his determination partly on the recent work of Mutto and Pollacci *(226)*. These workers cultured both *Coniothyrium Pirinum* and *Phyllosticta Pirina,* and as a result found the change of spore colour was a constant character of the former and did not occur in the latter species. They also studied *Coniothyrium tirolense* Bubak, and satisfied themselves that it was identical with *C. Pirinum* Sheldon, to which name it has priority. No change in spore colour has been noted in the New Zealand species, either in nature or in cultures. Dr. Butler further states: "It appears quite probable, therefore, that the true *Ph. Pirina* Sacc. is not recorded from America, and that all the records from that continent should be referred to a *Coniothyrium.*"

From the foregoing it would appear that the fungus constantly associated with these spots should be referred to *Phyllosticta Pirina* Sacc. From the fact that this species is constantly associated with this particular spot, that the spots are invariably circular (save where confluent), and that they occur on apple leaves throughout New Zealand, it would appear probable that this is the causal organism.

The life-history of this species is unknown, consequently the method of overwintering cannot be given. Reasoning from a knowledge of similar organisms, it is probable that the fungus overwinters in fallen leaves that have escaped desiccation; from these in the spring spores are produced, which are carried to trees in the vicinity, probably by the wind. There they infect maturing leaves, especially those of young trees that have not been sprayed. On these leaves fructifications are produced, which infect other trees in turn.

PREVENTIVE TREATMENT.

As the disease is one of slight importance, it would be unnecessary to go to any extra expense in attempting its control. Nevertheless, it damages the foliage to a certain extent, and in consequence is worthy of a little time expended on its control.

It is suggested where a regular spray schedule is followed, that summer sprays be applied also to young trees in the block, for too frequently are these overlooked; and doubtless it is from these young trees that the disease spreads to sprayed trees in the vicinity. This is a precautionary measure that could also well be followed where spraying for black-spot is being carried out.

SUMMARY.

1. Circular-spot is a disease probably caused by the fungus *Phyllosticta Pirina.*

2. It attacks the leaves of the apple, forming thereon small, circular, ashy-grey or ochraceous spots.

3. The damage to the tree is slight, consequently special control measures are unnecessary.

For literature references regarding this disease, see bibliography, p. 349, numbers *92, 187, 226, 267.*

DIPLODIA-CANKER, Diplodia Griffoni (Griff. et Maubl.) Saccardo and Traverso *(268)*.

Diplodia-canker ranks second in importance only to black-rot as a canker-forming disease of the apple. It was first recorded for New Zealand in 1916, from specimens forwarded to Kew by Waters. It has been confused by several authorities with black-rot, but recent cultural work performed in this laboratory *(122)* shows that the diseases are quite distinct.

The disease appears to have a limited distribution, for elsewhere it has been recorded only from England *(25)* and France, where it appears to be a minor one. So far as is known at present, in New Zealand it is confined to the apple, although in France it has also been recorded on the pear.

APPEARANCE AND EFFECT UPON THE HOST.

Diplodia-canker is prevalent on young laterals, but is not confined to these, for occasionally it is found on two and three-year-old wood. The attacked lateral is soon girdled, and the leaves wilt and turn brown, thus rendering noticeable the presence of the disease, for these wilted shoots present an appearance very similar to those infected with fire-blight.

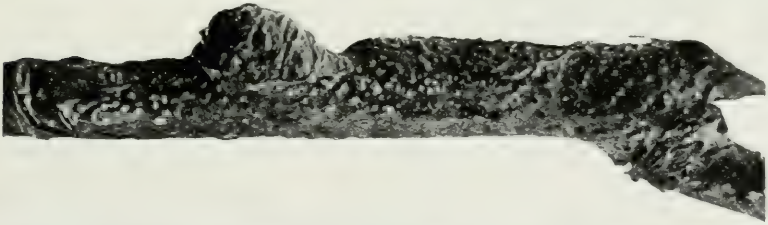


Fig. 55. DIPLODIA-CANKER ON TWO-YEAR-OLD APPLE BRANCH. × 2. Point of entry through woolly-aphis injury. Note the numerous pycnidia.

Photo by Author.

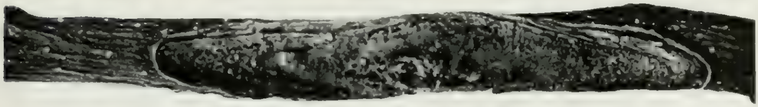


Fig. 56. CANKER ON THREE-YEAR-OLD BRANCH. Natural size. Note the sunken nature of the canker, and the zoned arrangement of the pycnidia. Point of entry through a broken stub.

Photo, W. D. Reid.

For explanation of terms, see glossary, p. xi.

When a canker thus formed is examined carefully it is seen to possess several features which separate it from black-rot and other cankers. It is depressed slightly, and is well defined from the healthy wood by one or more deep crevices with slightly raised margins. The colour is a distinct reddish-brown, with a conspicuous arrangement into light and dark bands, giving the whole canker a zoned appearance (Fig. 55). It will be remembered that the black-rot canker also is zoned; in this case, however, the zones are due to definite crevices, and not to colour. Diplodia-canker is rendered still more conspicuous on account of the whole surface being studded with the fructifications of the causal organism. These appear as small conical elevations, also arranged in zones (Fig. 56).

On older wood elliptical sunken cankers are formed. They are as a rule confined to one side of the branch, so girdling does not occur; consequently in the absence of wilted leaves this stage is easily overlooked (Fig. 56). For a time they present an appearance similar to cankers on the laterals; later they change to a dull brown, and in very old specimens the bark may fall away in strips, exposing the wood and giving to the wounds a ragged appearance.

The author has not found this fungus on fruits in nature, but when artificially innoculated into apples it produces a firm brown rot. On the surface appear numerous black raised points, the fructifications of the fungus.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

There are two spore stages in the life-cycle of this fungus. Shortly after a canker is formed numerous black papillae appear beneath the dead bark. Microscopic examination shows these to consist of small, flask-shaped pycnidia (Fig. 57), containing very numerous, large, one-celled, colourless conidia. This is the first or *Macrophoma* stage (Fig. 58). Should the canker persist for some time the spores change to dark brown and become one-septate, producing the second or *Diplodia* stage (Fig. 59). The latter is comparatively rare, the abundant stage being *Macrophoma.* These stages have been connected with the aid of cultures *(122)*. *Macrophoma* spores were sown on various culture media, and after a time in certain of the media appeared the *Diplodia* stage.

The fungus is apparently able to penetrate the tissues only through some injured surface. Field observations show that the chief source of infection is through woolly-aphis injuries (Fig. 55), but infection through stubs left as a result of careless pruning is not uncommon. Should a spore be carried to such a surface it may germinate and produce a hypha, which penetrates into the tissues and there branches repeatedly to form a mycelium. The hyphae

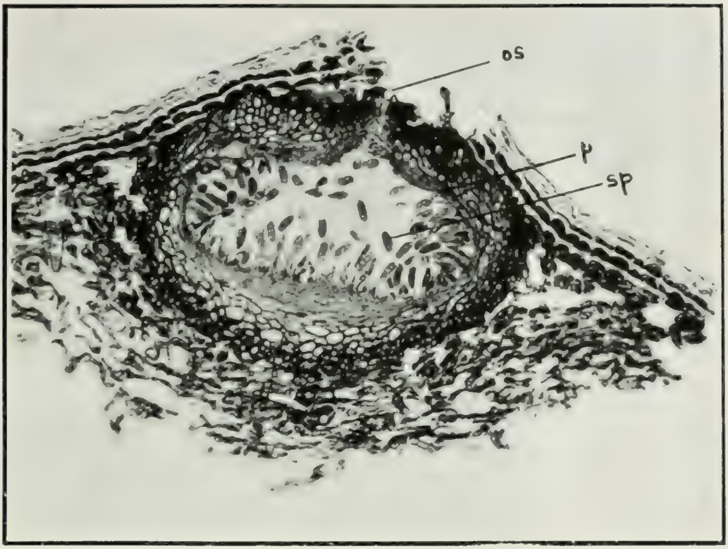


Fig. 57. PHOTOMICROGRAPH OF A SECTION THROUGH A PYCNIDIUM. × 75.
p. Pycnidial wall; *os.* ostiolum; *sp.* conidia.

Photo by Author.

penetrate into the tissues of the cortex and wood, growing radiately outwards from the infection centre. Should the shoot be a small one, girdling quickly follows. Sections through old cankers show that the hyphae of the fungus penetrate through cortical and wood tissues, killing and discolouring them.

The mycelium persists in a canker, especially one on an older limb, for two or more seasons. Under favourable conditions it produces fructifications on the surface of the canker throughout the whole of this period. These fructifications are flask-shaped receptacles (Fig. 57), opening by an ostiolum (Fig. 57, *os*) on to the free surface. The enclosed conidia are embedded in hygroscopic mucilage, which in a humid atmosphere absorbs water, swells, and is forced out through the ostiolum to the surface, where it appears as a gelatinous tendril in which are embedded the conidia.

The mucilage is dissolved by rain, and the conidia lie free on the surface of the bark. When dry they are carried long distances by the wind. It is probable that insects play a part in their distribution. The fungus is not confined to the living host, for it has frequently been obtained on dead apple twigs lying on the ground in the orchard and in heaps of prunings. Conidia from such

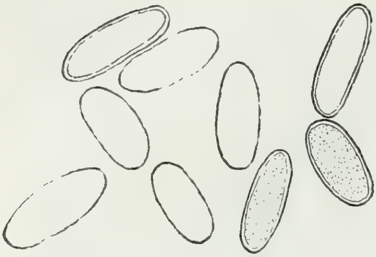


Fig. 58.

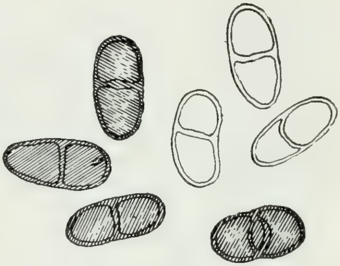


Fig. 59.

Fig. 58. CONIDIA (Macrophoma stage). × 500.

Fig. 59. CONIDIA (Diplodia stage). × 500.

Original.

sources give the same growth in culture media, and produce the same rot in apple fruits as those taken from cankers. The author has been able to infect apple laterals with spores *(Macrophoma)* produced in culture by introducing them into wounds artificially made in the cortex, but has failed to infect leaves either directly or through wounds in the epidermis.

REMEDIAL TREATMENT.

It has been shown that this organism is spread by conidia produced from fructifications embedded in the dead bark of cankers, and that the fructifications may be formed at any time during the life of the canker, the mycelium being perennial. It is seen that twigs left on the ground or in heaps of prunings—twigs on which the fungus is living as a saprophyte—are also a source of infection. Further, it has been shown that infection can occur only through wounds in the bark, principally through injuries caused by woolly-aphis.

The following remedial treatment is recommended:—

(1) Removal of sources of infection; and

(2) Prevention of infection by wound-treatment.

Unfortunately, in the latter case this would necessitate the control of woolly-aphis—a difficult task—as it is through injuries formed by these aphids that the majority of infections occur. This phase may be ignored, for if the sources of infection be removed the disease will soon become negligible. This would not prove a difficult matter, for, so far as is at present known in New Zealand, the fungus is confined to the one host-plant. The spores have not been obtained, even on dead wood, on other than the apple.

SUMMARY.

1. Diplodia-canker is a fungous disease confined to the apple. It forms cankers on laterals and branches. It has not been found on leaves or fruits in nature.

2. Cankers caused by it may readily be recognised on account of the characteristic light and dark bands of reddish-brown colour.

3. There are two spore stages in the life-cycle, a *Macrophoma* followed by a *Diplodia* stage. They have been connected with the aid of cultures.

4. The fungus overwinters in the cankers and on dead twigs on the ground and in pruning-heaps.

5. It is a wound parasite, entering principally through woolly-aphis injuries.

6. Remedial treatment recommended is the removal of sources of infection.

For literature references regarding this disease, see bibliography, p. 349, numbers *25, 122, 268.*

CHAPTER XV.

POME-FRUIT DISEASES.

(Continued.)

(a) Fungous Diseases.—Continued.

FABRAEA-SCALD, Fabraea maculata (Lev.) Atkinson *(28)*.

Syn.: *Entomosporium maculatum* Lev.

Black-spot; fruit-spot; leaf-blight; leaf-scald;
quince fruit-spot; scald.

This disease is widely spread, for it has been recorded from Europe, North America and Australia. In New Zealand it has been found only on the pear and quince, but in North America it has been recorded in addition on the hawthorn and apple.

It was first recorded for New Zealand by Kirk *(177)* in 1894.

APPEARANCE AND EFFECT ON THE HOSTS.

In New Zealand fabraea-scald is common wherever the quince is grown, appearing on the leaf, shoot, and fruit; on pear it is not uncommon on the fruit, but seldom has been found on the leaf.

On leaves, shortly after they unfold from the bud, the disease appears first in the form of minute, purplish, slightly raised spots on the upper surface (Fig. 60, *b*). In the centre of each spot a small white dot becomes visible—the opening through which the conidia escape. The spots gradually increase in diameter, at the same time changing in colour, and appear on the under-surface of the leaf. They may enlarge until they are about 5 mm. in diameter, when they appear at first dark brown, later changing to ashy-grey (Fig. 60, *a*), or they may become much larger and more irregular in shape, and reddish-brown in colour. Finally, these irregular spots may coalesce and form large irregular areas, which eventually may cover the greater part of the leaf.

In or near the centre of the spots are minute black specks, the fructifications of the fungus. On the leaf-stalks (petioles) small cankers are sometimes formed; when these occur the leaf is killed outright and falls away.

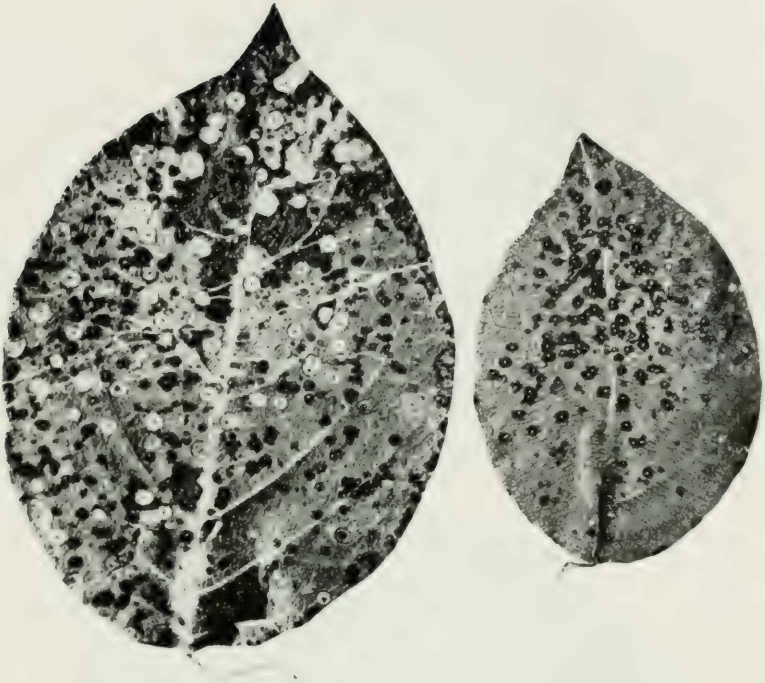


Fig. 60. **QUINCE LEAVES INFECTED WITH FABRAEA-SCALD.** Natural size. *a.* Leaf showing both late and early infection; *b.* Leaf showing early infection.
Photo by Author.

On laterals small, elliptical, somewhat sunken spots are produced. The spots are dark brown, with a slightly raised, lighter-coloured margin. These spots may remain small and inconspicuous, and are thus readily overlooked, or they may enlarge until the shoot becomes girdled and dies, becoming then noticeable. Owing to the small size of most of these spots on the shoots, shoot-infection has frequently been overlooked; but this condition plays an important part in the perpetuation of the disease. The significance of this will be discussed below.

On fruits the disease forms spots which differ slightly on different hosts.

On pear-fruits the spots at first are small, circular, and a rich carmine. They gradually become black in the centre, and become surrounded by a light reddish-brown zone. At this stage spots superficially resemble those caused by pear-scab (*Venturia*

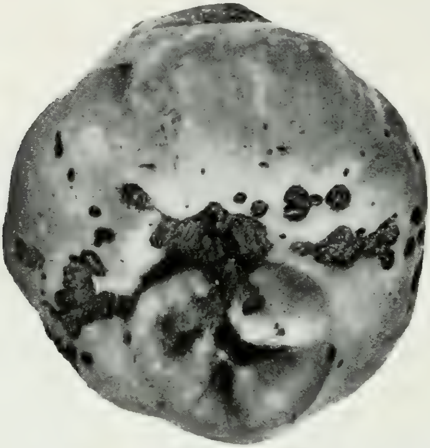


Fig. 61. FABRAEA-SCALD ON QUINCE FRUIT. × ½.

Photo, H. Drake.

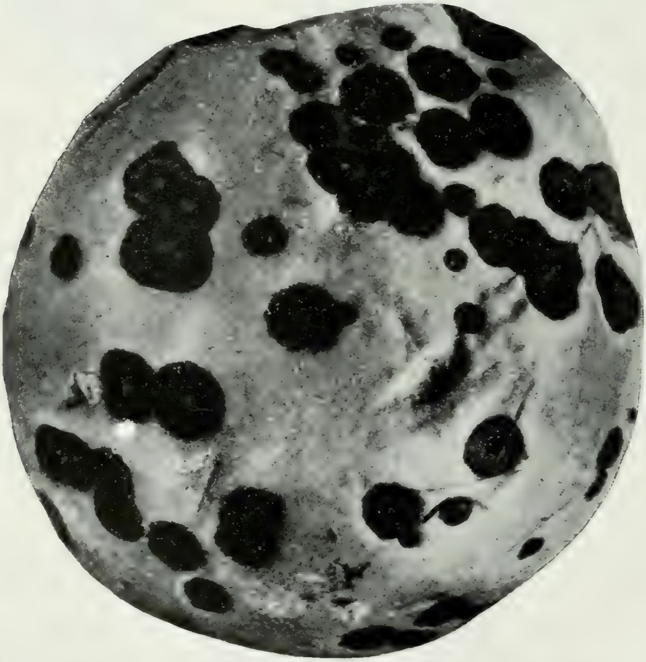


Fig. 62. QUINCE FRUIT SHOWING SPOTS CAUSED BY FABRAEA-SCALD. Natural size.

Note that the spots are sunken, black and frequently zoned.

Photo by Author.

Pirina), and are frequently mistaken for them. Finally, the surface of the spot becomes roughened and broken, due to the epidermis being raised in the form of a small blister, which is ruptured by the developing fructifications. Frequently the disease forms large irregular cracks on the surface of the fruit; this occurs especially when developing fruits become infected, for the "cambium" being damaged, further growth in the region of the spot is prevented.

On quince-fruits dark-brown or black spots are formed. As these increase in size they become somewhat sunken, darker in colour, and often zoned. They may attain to a size of 15 mm. or more in diameter. These spots may remain isolated, or coalesce to form large irregular areas. In the latter case the fruit usually becomes misshapen (Fig. 61), and often falls prematurely. Cracking sometimes occurs as in the pear.

Thus on pear the spots are usually small, brightly coloured, and much roughened, while on quince they are dull brown or black, sunken, and usually much larger in size.

ECONOMIC IMPORTANCE.

Fabraea-scald attacks leaves, shoots and fruits. On leaves it forms spots which, if numerous, may so damage the leaf as to cause it to fall prematurely. On shoots its effects generally are slight, but in cases of severe infection the laterals may be killed outright, especially at the tips. The chief source of loss is through the fruit, for on them the disease forms large discoloured spots and frequently crevices, which disfigure and render the fruit unsaleable. Through the crevices the spores of secondary fungi enter and cause rapid decay.

Nursery stock frequently is attacked and partially or totally defoliated; consequently infected trees make little or no growth, and are thus rendered unsaleable.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

The disease is caused by *Fabraea maculata*, a fungus possessing two spore-stages in its life-cycle. The first or conidial stage (formerly known as *Entomosporium maculatum*) is parasitic, occurring on living leaves, shoots, and fruits, forming thereon the discoloured spots described above. The second or ascigerous stage is saprophytic, appearing only on dead leaves which have lain on the ground for some months.

The disease first appears in the spring, shortly after the leaves unfold from the bud. Infection of these leaves would appear to occur either from ascospores produced from fallen leaves in which

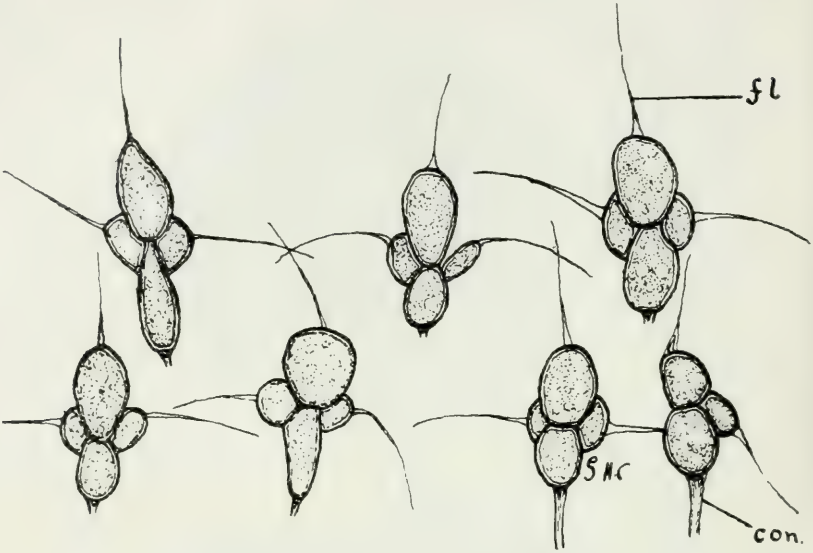


Fig. 63. CRUCIATE CONIDIA OF FABRAEA MACULATA. × 1,000. *fl.* Flagellum; *con.* conidiophore.

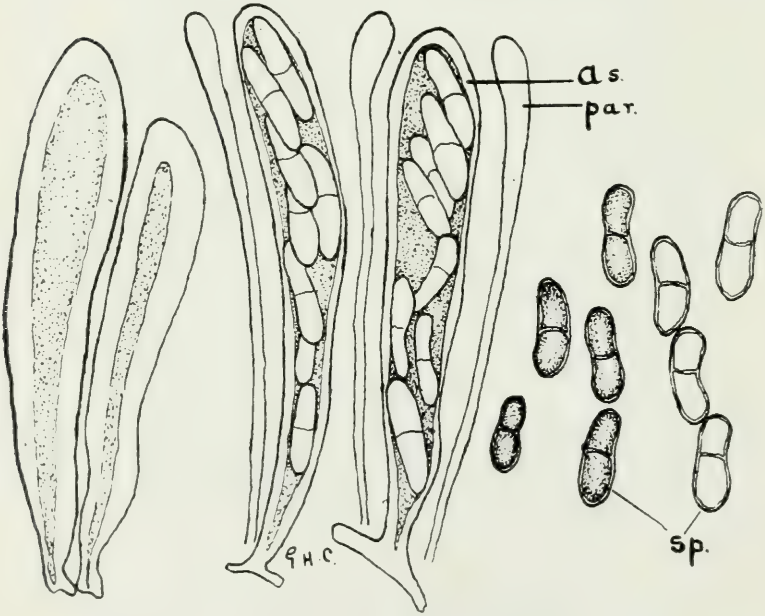


Fig. 64. ASCI, PARAPHYSES AND ASCOSPORES. × 1,000. *Original.*

the fungus has overwintered, or from conidia produced from mycelium which has overwintered in small cankers (spots) on the shoots.

The spores (ascospores or conidia) are carried to the developing leaves by wind or other agency, where, should conditions prove favourable, each germinates and produces a hypha which penetrates the epidermis and enters the tissues, where it forms a mycelium, the hyphae of which derive their food substances from the host-cells. The hyphae spread outwards and downwards, killing the cells with which they come in contact, the dead cells forming the discoloured spots characteristic of the disease.

After a time the hyphae form beneath the epidermis a small flattened pycnidium in which the spores are developed. The pycnidium as it develops pushes up the epidermis as a small blister, finally rupturing it and becoming exposed. The pycnidium does not possess an ostiolum through which the spores emerge, but ruptures irregularly, the ruptured margins standing above the surface of the leaf or fruit, thus giving to the spot the roughened appearance described above. The conidia are so characteristic that their presence is a certain indication that the spots are due to this fungus. Each conidium is four-celled, the cells being arranged in the form of a cross (cruciate). From the free surface of each cell is produced a fine flagellum (Fig. 63, *fl*). The conidia are hyaline and are borne on short conidiophores which arise from the base of the pycnidia.

From the first-formed spots spores are produced which infect developing leaves and fruits; conidial infection continues in this manner throughout the growing season. In the autumn infected leaves fall to the ground, and the mycelium within the spots remains dormant until the late winter or early spring, when it produces a second fructification. This appears on the free surface of the leaf as a pale-yellow, cup-shaped apothecium, so minute as barely to be visible to the eye, being in fact only about 0.5 mm. in diameter. The inner surface of this structure is lined with a closely-packed layer of asci and paraphyses. Each ascus contains eight, hyaline, two-celled ascospores (Fig. 64).

The connection between the conidial and ascigerous stages has been experimentally proved by Atkinson *(28)*. He sowed ascospores on culture media and obtained conidia; with the conidia thus produced he inoculated leaves and produced the spots characteristic of this disease. On account of Atkinson's work it is frequently stated in the literature dealing with this disease *(26)*, *(293)*, *(297)* that the method of overwintering of the causal organism is by means of resting mycelium in the fallen leaves, this mycelium in the spring producing apothecia and ascospores, the latter infecting leaves as they emerge from the buds. But it would appear that the ascigerous stage is by no means as common as we are led to believe. The author has made a continuous search for the ascigerous stage of fabraea-scald, but without success, and all attempts to induce sporulation under artificial conditions have failed *(124)*.

Furthermore, on failing to obtain apothecia in New Zealand, the author wrote to several authorities in North America for specimens. In reply they stated that no material was available. Professor H. M. Fitzpatrick, of Cornell University, stated that apparently this stage has not been collected and recorded since the type material was collected and described by Atkinson *(28)*. Professor Fitzpatrick kindly loaned part of the type material, from which the accompanying illustrations of asci and ascospores have been drawn.

Thus we are led to seek another means whereby the fungus is able to overwinter. It is improbable that the conidia are able to live through the winter months on the fallen leaves, for none were present on the many leaves examined. Several authorities claim that the mycelium in infected twigs is perennial, and that this mycelium in the early spring produces conidia which infect the developing leaves. Although conclusive evidence of this is wanting, it is probable that such is the case, for it is obvious that some such additional source of infection is necessary in order to account for the heavy infection that occurs at blossoming-time, and we have already seen that the ascigerous stage is apparently rare.

CONSIDERATIONS REGARDING CONTROL.

It would appear that there are two probable methods whereby this organism may overwinter—(1) by resting mycelium overwintering in the fallen leaves (producing apothecia and ascospores in the spring), and (2) by resting mycelium in the shoots (producing conidia in the spring).

Thus control measures would consist firstly in the removal of these sources of infection, and secondly in the prevention of infection by coating developing leaves and fruits with some suitable fungicide. It would be difficult to detect the cankers on laterals, so that the removal of such infected shoots is not stressed; but in order to minimise this source of infection it is suggested that quince-trees regularly be pruned, all weakly growth removed, and the trees opened out in such a manner as to facilitate spraying—

for too often are these trees neglected. And it must be borne in mind that the fungus may spread from quince to pear, consequently it is essential that the quince-trees be not overlooked during pruning and spraying operations.

Special attention should be paid to the eradication of suckers, for small cankers frequently are present on these growths.

To minimise infection from fallen leaves it is suggested that the orchard be ploughed in the late autumn after all the leaves have fallen, and that all portions beneath the trees not reached by the plough be turned over with a spade.

CONTROL.

As in essentials the life-history of fabraea-scald is very similar to that of black-spot and pear-scab, it follows that remedial treatment would be of a similar nature. So that, in addition to pruning and ploughing, the spray schedule on p. 85 should be followed. As this is the schedule recommended for pear-scab control, it follows that where the latter disease is prevalent in a district no further spray treatment will be required in order to combat fabraea-scald on the pear.

SUMMARY.

1. Fabraea-scald is a fungous disease attacking the pear, quince, and hawthorn. It infects leaves, fruits, shoots (especially water-shoots) and suckers.

2. The causal organism is *Fabraea maculata,* a fungus with two spore stages in its cycle; the first or conidial stage is parasitic, the second saprophytic, appearing in the spring upon leaves which have escaped desiccation.

3. The disease probably overwinters in the form of resting mycelium in living shoots, and produces conidia in the spring. It also overwinters as resting mycelium in fallen leaves, producing apothecia in the spring. The latter stage would appear to be rare in nature.

4. Control consists in the spraying of infected trees according to the schedule on p. 85. Thinning out of growths in quince trees is also recommended.

For literature references regarding this disease, see bibliography, p. 349, numbers *26, 28, 124, 162, 177, 293, 297.*

PEAR-SCAB, Venturia Pirina Aderhold *(22)*.

Syn.: *Fusicladium Pirinum* (Lib.) Fcl.
Black-spot.

Pear-scab is prevalent throughout New Zealand, with the exception of those localities—Central Otago, parts of Marlborough and Auckland—in which black-spot also is absent, for the distribution of the two diseases is the same. It occurs also in Europe, North America, South Africa and Australia. This disease is confined to the pear.

The conidial stage was first recorded for New Zealand in 1906 by Kirk *(187)*, and then only incidentally, but pear-scab must have been here much earlier than this, and has probably erroneously been listed in the earlier reports as fabraea-scald; the ascigerous stage was recorded by Miss Curtis *(125)* and the author *(108)* in 1921. The two stages were first connected with the aid of cultures by Aderhold *(22)*.

The disease is very similar in appearance to black-spot, and by orchardists is usually regarded as identical. The causal organism differs in several details of structure of the fructifications, as well as in its inability to infect any host other than the pear. It causes a leaf and fruit spot (Fig. 65) similar in appearance to black-spot, while its life-history and control are similar. It differs from black-spot in that it commonly produces conidia on young shoots and laterals (Figs. 66, 67), a condition known for the past fifteen years to exist in New Zealand. The author has shown *(108)* that conidia have been produced continuously on shoots over a period of nine months, and that viable conidia occurred on shoots during the whole of that period. There is little doubt therefore that with this species shoot-infection is one of the means, if not the chief one, of carrying the organism over the winter months. The fact must not be lost sight of, however, that perithecia are produced abundantly on fallen leaves, and that ascospores produced therein infect the leaves and fruits of the pear in the spring.

CONTROL.

As the life-history of this organism is similar to that of black-spot (p. 132), it follows that the methods of control are similar. Therefore plough under all fallen leaves in the late autumn, and turn over with a spade those portions beneath the trees left untouched by the plough. Spray according to the formula on p. 85, but if the disease is at all troublesome, substitute bordeaux 3-4-50 for lime-sulphur, for pear fruits and foliage will tolerate this spray.

For explanation of terms, see glossary, p. xi.

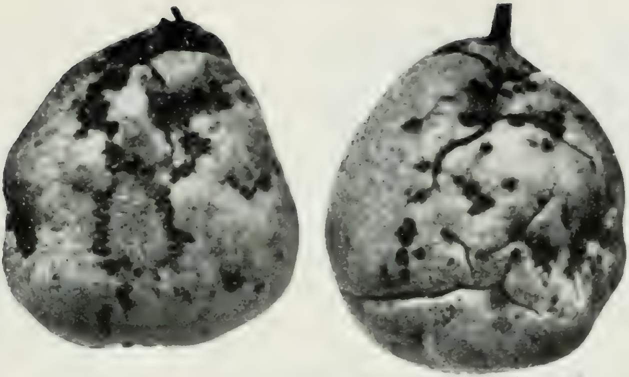


Fig. 65. PEAR-SCAB LESIONS ON PEAR FRUITS. × $\frac{2}{3}$.
Note the irregular crevices (on fruit on right) that have followed infection.
Photo. H. Drake.

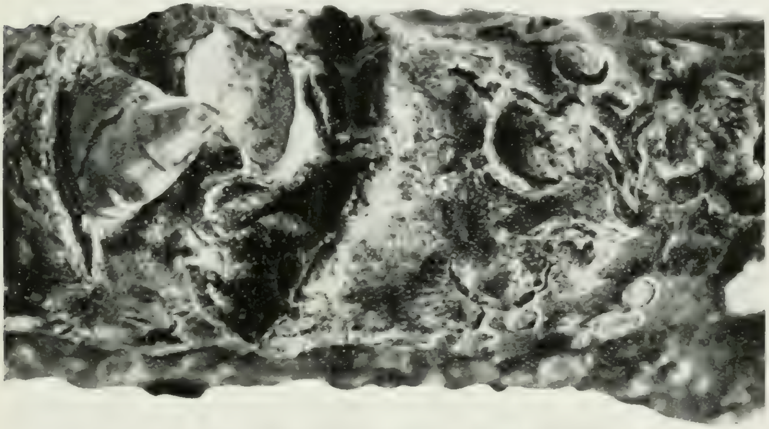


Fig. 66. USUAL FORM OF PEAR SHOOT-INFECTION. × 4.
Note the blistered areas.
Photo, E. Bruce Levy.

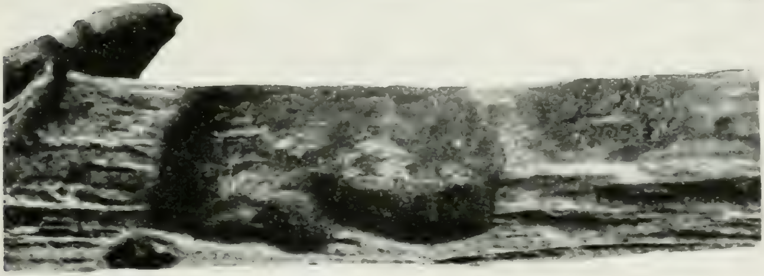


Fig. 67. UNUSUAL FORM OF PEAR SHOOT-INFECTION. × 4.
Note depressed areas.
Photo, E. Bruce Levy.

SUMMARY.

1. Pear-scab is a fungous disease attacking leaves, shoots and fruits of the pear. It is confined to this host, and will not infect the apple.

2. The causal organism is *Venturia Pirina,* a fungus with two spore stages in its life-cycle. Its life-history is similar to that of the black-spot organism.

3. The fungus overwinters in the form of resting mycelium in fallen leaves and living shoots; but under favourable conditions it is capable of producing viable conidia through the winter months.

4. It may be controlled by systematic spraying, especially if bordeaux 3-4-50 is used as a summer spray. Control is facilitated by the destruction of fallen leaves.

For literature references dealing with this disease, see bibliography, p. 349, numbers *22, 108, 125, 187.*

POWDERY-MILDEW, Podosphaera leucotricha (Ell. et Ev.) Salmon *(270).*

Syn.: *Sphaerotheca leucotricha* Ell. et Ev.; *S. Mali* Burr.
Apple-mildew; mildew.

Powdery-mildew, although very frequently neglected by the orchardist, is one of the most serious diseases with which he has to contend. It is prevalent throughout the fruitgrowing areas of New Zealand, and becomes especially troublesome during the late summer and the early autumn. It would appear that this disease originated in western North America, and from there it has spread to almost every country where apples are grown, for it has been recorded from Europe, Asia, and Australia.

In New Zealand powdery-mildew is confined to the apple, but in Japan it occurs on an additional host, *Pirus toringo,* and in North America has been recorded (though seldom) on the pear. So far as the author is aware, no apple varieties are immune, but certain varieties are more susceptible to attack than are others, Cox's Orange, Jonathan, Sturmer, Cleopatra, London Pippin, Gravenstein, Northern Spy, and Dunn's Favorite being usually severely infected.

The conidial stage was first recorded for New Zealand by Blackmore *(44)* in 1901; the perithecial by the author *(120)* in 1923.

APPEARANCE AND EFFECT ON THE HOST.

Trees infected with powdery-mildew present a very sickly appearance; they become partially defoliated, and carry about one-fourth the leafage of a normal tree. The shoots are often bare at

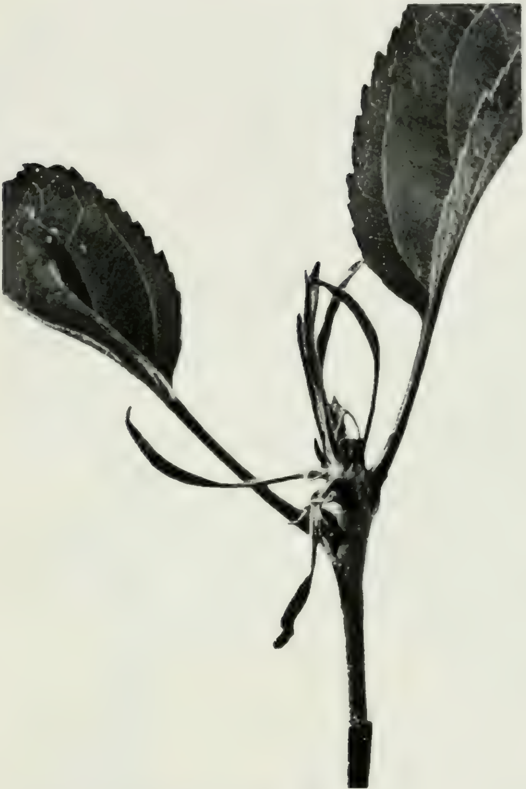


Fig. 68.

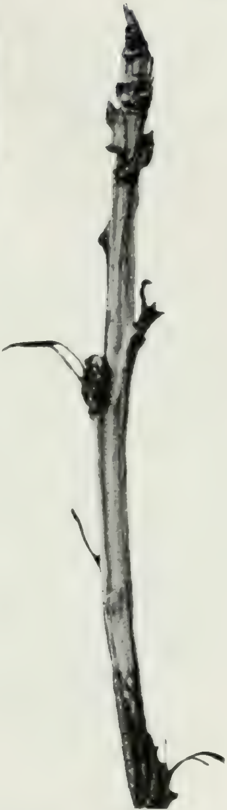


Fig. 69.

Fig. 68. POWDERY-MILDEW ON TIP OF A STURMER LATERAL. $\times \frac{1}{2}$.
Further growth is prevented, and the subsequently formed leaves remain small and strongly curled.

Fig. 69. INFECTED APPLE LATERAL FROM WHICH THE MATURE LEAVES HAVE FALLEN. $\times \frac{2}{3}$.
Note the stunted leaves, and especially the white mycelial mass covering the upper portion.

Photos by Author.

their tips (Fig. 69), and are partly covered with the glistening white masses of the fungus. The fruit is smaller than the normal, and usually disfigured.

Powdery-mildew attacks leaves, shoots, blossom-buds, and fruits. On the leaves it first becomes noticeable in the form of small, irregular, white or greyish, cobwebby patches. These make their appearance first on the under-surface of the leaf, and gradually spread until both surfaces may become entirely covered, when the leaf appears as if dusted with flour. Leaf-infection occurs as soon as the leaves emerge from the bud, and the fungus spreads progressively from these to subsequently formed leaves. Infected leaves become narrower and rather longer than the normal. At first they appear somewhat blistered, then the edges gradually curl inwards until they appear markedly distorted (Fig. 68). Later they become brittle and have a scorched appearance. Finally, they change to a bronze colour and ultimately fall away.

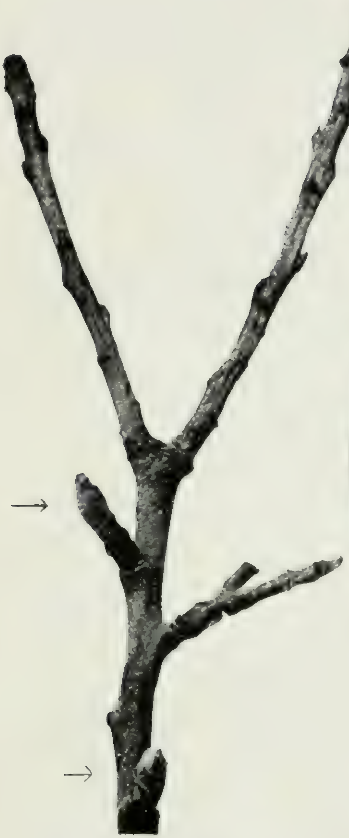
Laterals are infected shortly after the leaves have emerged from the buds and immediately after they have begun to increase in length. Infection occurs from the leaves, the hyphae growing down the leaf-stalk (petiole) to the young shoots. As a result of infection growth is somewhat checked, consequently the buds are more closely set together (Fig. 71). When infection is severe the tips of the shoots are killed, and the following season several small shoots spring from below the killed area, the resultant shoots presenting a "bushy" appearance (Fig. 71). The fungus continues to develop on the shoots until they become covered with a white felt-like mass, more abundant near the tip, which consists of the mycelium or vegetative portion of the fungus (Fig. 69).

Infected blossom-buds are somewhat smaller than the normal, and are conspicuous by reason of their covering of white mycelium. When the buds expand and the blossoms appear, the calyces and stalks are seen to be somewhat deformed and altered in colour. Infected blossoms rarely set fruit, and are invariably later in appearing than the normal blossoms.

The fruits are infected shortly after blossoming, and at this stage may be seen to be partially covered by the fungus. At this stage the delicate epidermis becomes damaged, so that later, when the fruits approach maturity, the epidermis is seen to be decidedly russeted, the markings appearing either as a delicate brown or yellowish tracery over the surface (Fig. 70), or as scabbed and deformed areas on one side, but more frequently on the stalk end of the fruit. This may later be followed by the appearance of concentric cracks which usually extend some distance into the flesh and afford opportunity for the entry of spores of soft-rot fungi; consequently fruit from trees infected with mildew rarely keeps well for any time. The author has not observed the hyphae of the fungus on other than very small fruits. The fruits of all varieties do not appear to be attacked, as russeting has not been observed on fruits of Cleopatra, although the leaves and shoots of this variety suffer severely.

ECONOMIC IMPORTANCE.

This disease causes the leaves to become much smaller in size, crinkled, brittle, and darker in colour. Infected leaves fall prematurely, so that about midsummer severely infected trees appear



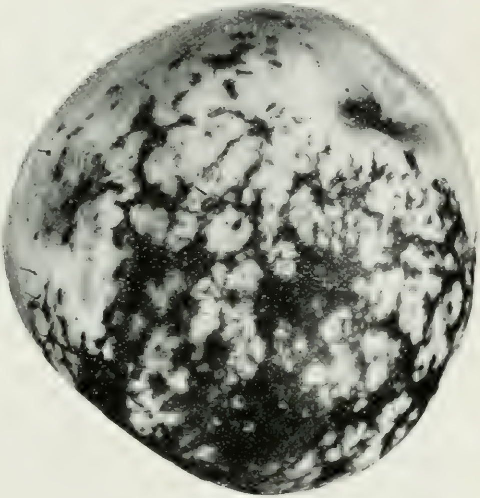


Fig. 70. DUNN'S FAVORITE APPLE FRUIT RUSSETED AS A RESULT OF EARLY INFECTION. Natural size.
Although not noticeable in the photograph, the near side is much deformed.

71. APPLE-SHOOT INFECTED THE PREVIOUS SEASON. × ⅔.
Note the bunchiness of the laterals, their small size, and the closeness and small size of the buds. Normal buds are indicated by arrows.

Photos by Author.

partially defoliated. Shoots, if infected early in the season, become stunted and often so weakened as to die at their tips, often losing their foliage, when they appear quite bare. Fruit-buds are damaged to such an extent that the resultant blossoms seldom set fruit. Fruits may be attacked while immature, with the result that at maturity they appear russeted and smaller than the normal. At the stem end they frequently become scabbed and cracked. In short, the effects of mildew infection are (1) the reduction of leafage and damage to the remaining foliage, (2) destruction of fruit-buds, (3) weakening and frequent killing of laterals, and

(4) reduction of the marketable value of the fruit by russeting, cracking, and frequent deformation. Further, young nursery stock may be damaged to such an extent that wood-growth is entirely prevented; consequently such stock becomes unsaleable.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Powdery-mildew is caused by *Podosphaera leucotricha,* a fungus having two spore stages in its life-cycle. The first or conidial stage is produced throughout the growing season on the felt-like masses of mycelium which cover the surfaces of infected leaves and shoots; the second or perithecial stage in New Zealand appears about the middle of March (although it would appear to be common in midsummer in North America) in the form of small black perithecia partially embedded in the mycelial masses. The conidial stage is the more important one, as apparently the perithecia play little if any part in the perpetuation of the organism.

If a small portion of the felt-like mass of mycelium is examined under a microscope it is seen to consist of very numerous, colourless, closely woven hyphae closely applied to the surface of the host (Fig. 72, *m*). From these at intervals arise upright conidiophores (Fig. 72, *con*) bearing on their free ends chains of colourless oblong conidia (Fig. 72, *c*). These are produced in such enormous numbers as to give the leaves and shoots upon which they may happen to be growing the appearance of being covered with flour. Should one of these conidia be carried by wind or other agency to the surface of a growing leaf or shoot, and conditions prove favourable, it germinates and produces a slender infection-hypha, which grows over the surface of the substratum, branching repeatedly to form a mycelium. This consists of very numerous interwoven hyphae, and derives its nourishment from the epidermal cells, into which small branches (haustoria) penetrate (Fig. 72, *h*) to absorb therefrom the necessary food substances. It is thus seen that with the exception of these small haustoria, all the fungus is superficial. The hyphae continue to spread over leaves and shoots during the whole of the growing season.

About the middle of March the perithecia make their appearance on the shoots, leaves, and petioles, appearing as small, globose, black objects densely crowded together, and partially embedded in the mycelium (Fig. 74). Each perithecium has on its free surface several bristle-like structures, which serve to characterise the species (Fig. 74). Within the perithecium is a single large ascus containing eight one-celled, colourless ascospores (Fig. 74, III.). Under humid conditions the perithecia absorb moisture and swell, and their walls become ruptured, allowing the ascospores to escape. Experi-

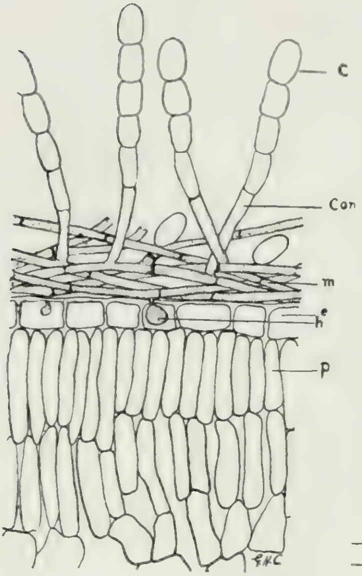


Fig. 72.

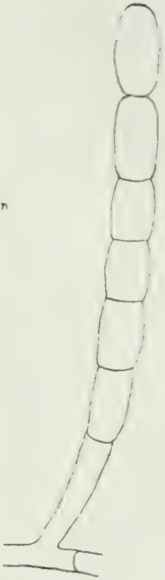


Fig. 73.

Fig. 72. SECTION THROUGH A LEAF INFECTED WITH POWDERY MILDEW. × 325.

c. Conidia; *con.* conidiophores; *e.* epidermis of leaf; *h.* haustorium; *m.* hyphae; *p.* palisade cells of the leaf.

Fig. 73. CONIDIOPHORE AND CHAIN OF CONIDIA, SHOWING METHOD OF SPORE PRODUCTION. × 600.

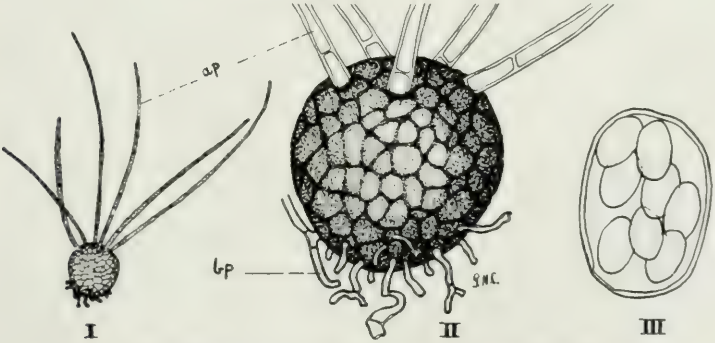


Fig. 74. I. PERITHECIUM OF PODOSPHAERA LEUCOTRICHA. × 85.
II. PERITHECIUM. × 330; note the apical (*ap*) and basal (*bp*) appendages.

III. ASCUS AND ASCOSPORES. × 330.

Original.

ments carried out in North America *(31), (145)* would tend to show that the perithecia play little or no part in the perpetuation of the disease, as attempts made to infect young developing leaves with ascospores invariably failed.

The fungus is carried over from year to year by the felt-like masses of mycelium, which cover the buds, spurs and tips of laterals, and by hyphae which are enclosed within the scales of infected buds. This mycelium remains more or less dormant until the spring, when conidia are produced from the hyphae, and these infect the leaves as they emerge from the buds, thus starting the disease afresh. Doubtless in many instances infection occurs from the hyphae within the bud-scales, before the leaves emerge. It thus becomes apparent that the persistent mycelium is the source from which the fungus is spread in the spring; therefore in combating the disease the elimination of this mycelium should be attempted before any spray is applied.

CONSIDERATIONS REGARDING CONTROL.

As has been shown, powdery-mildew is perpetuated by the persistent mycelium (Fig. 69); therefore where systematic attempts are being made at control attention should be given to the removal of this source of infection. If all infected shoots and buds were removed, then the disease would be entirely eliminated and spraying become unnecessary. Unfortunately, this cannot be accomplished in a commercial orchard, partly because the time required would be too great and the labour involved too costly, but principally because the disease is in part carried over in infected buds, which in many instances are not apparent from a casual inspection. Furthermore, infection would still be liable to occur from windborne spores from neglected orchards in the vicinity. Nevertheless, cutting out would reduce infection, especially spring infection, to such an extent that control by spraying would be rendered comparatively simple.

The crop would not be in any way lessened by the removal of infected shoots and fruit-buds, for infected buds are incapable of setting fruit. Therefore systematic control of powdery-mildew must commence with the cutting-out of visibly infected material. This may be readily accomplished during the winter pruning, especially in New Zealand, where the system of pruning is such that practically every shoot is dealt with. If the disease were much in evidence during the late summer a further cutting-out could be undertaken.

From time to time numerous sprays have been recommended for mildew-control. Bordeaux, lime-sulphur, "iron-sulphide solution," precipitated sulphur, and several variants of these have all been tried. Undoubtedly precipitated sulphur has given the most satisfactory results.

The iron-sulphide solution has been favoured by numerous growers (this is a solution of lime-sulphur to which iron sulphate ($FeSO_4$) has been added), but consideration will show that this is merely a solution of precipitated sulphur and iron sulphide (FeS), the latter compound possessing little, if any, value as a fungicide.

CONTROL.

As powdery-mildew is carried over the winter months by the mycelial masses which remain on the shoots and in the bud-scales, it is necessary that as many of these as are seen be removed during the winter pruning. This should be followed by spray applications according to the schedule on p. 86.

Where a regular spray schedule for black-spot control is being followed, it will be found that mildew is held in check somewhat, but not entirely, as lime-sulphur is not satisfactory as a controllant of mildew. A dual spray—lime-sulphur 1-120 + precipitated sulphur 10-100—is therefore recommended in place of lime-sulphur alone. The second black-spot spray should be lime-sulphur 1-30, in preference to bordeaux 3-4-50, as the latter is of little use against mildew.

The first two sprays in the schedule prevent leaf infection from mycelium overwintering in the buds, No. 2 especially preventing russeting of fruits. The third and fourth sprays prevent infection from outside sources. It should be realised, however, that spraying is effective only where cutting-out has been practised in the winter. No. 3 spray should be followed by cutting-out if the disease is prevalent.

SUMMARY.

1. Powdery-mildew is a fungous disease attacking leaves, shoots, buds and fruits. It occurs on apple, pear and (in Japan) *Pirus toringo.*

2. The causal organism is *Podosphaera leucotricha.*

3. The disease overwinters by means of resting mycelium on the shoots and in the bud-scales. It is spread in summer by means of conidia produced from mycelium covering leaves and shoots.

4. It may be controlled by the systematic cutting-out of infected shoots and buds during the winter pruning, and by spraying according to the schedule recommended.

For literature references, see bibliography, p. 349, numbers *31, 44, 120, 145, 270.*

ROOT-FUNGUS, Rosellinia radiciperda Massee *(205)*.

Syn.: Root-rot; New Zealand white root-rot.

Root-fungus is one of the most destructive diseases with which the orchardist has to contend. It is prevalent throughout the orchard areas of the North Island, and has been found in certain localities in the South, where it has been introduced with nursery stock.

This disease is confined to New Zealand, but similar conditions, caused by similar organisms, are known the world over. It attacks a wide range of hosts, among which may be enumerated apple, apricot, cherry, chestnut, currant, gooseberry, hawthorn, peach, pear, plum, privet, and quince. It also occurs on many indigenous plants. It has been claimed that it attacks such plants as cabbage, dock, fern, potato and sorrel *(326)*, but the experience of the author is that it is limited in its attack to woody perennial plants, and that such plants as the cabbage, potato, etc., are infected by various soil fungi, but not by the one in question. The peach is generally considered to be immune, but such is not the case, for the disease has on occasion been found on this host.

APPEARANCE AND EFFECT ON THE HOSTS.

Root-fungus, being a soil organism, is confined in its attacks to the roots and crowns of the hosts. These it destroys by killing the cortex and conducting tissues, and in consequence the infected tree dies. Death may occur rapidly or may be a gradual process, the latter being the more common condition. The first indication of the presence of the disease is a gradual yellowing of the foliage, followed by a certain amount of premature leaf-fall. Trees make little or no growth, and appear starved, and the fruit is usually small and shrivelled. If the tree persists for several seasons it may be seen to die gradually from the tips of the main leaders, consequently such trees present a "stag-head" appearance. This may be general over the whole tree, or, as is more frequently the case, one or more branches only, usually on one side of the tree, will show this condition.

When the root system is examined, it will be found that when one or two branches show signs of being starved, or show the stag-head appearance, one or two main roots on that side of the tree will be infected, and often killed outright.

When the whole tree is affected the majority of the roots, save a few superficial ones, will be found to be infected, and in exceptional cases where the tree wilts and dies in one season, both roots and crown will be found infected. If the cortex be cut away from the diseased roots, a fine white layer, the mycelium of the fungus, will be found lying immediately over the wood. The stag-head appearance, general starved appearance of the tree, decayed roots and crown, and presence of the layer of mycelium are certain indications of the presence of this fungus. The starved appearance is due to the fact that the roots being damaged, little or no crude food substances can be carried to the branches and leaves (there to be elaborated into available foods), thus the tree actually suffers from starvation.

ECONOMIC IMPORTANCE.

Infection leads to the loss of the tree, for an infected tree does not recover, and as trees of any age may be infected, it follows that the disease may inflict a heavy loss, for in certain localities areas of an acre or more in extent are sometimes killed. An illustration of this occurred near Rotorua, where a small property of four acres, at one time in forest, was cleared and planted in apples and pears. The following year all the trees in the block were killed outright.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

There exists a certain amount of uncertainty regarding the identity of the causal organism.

Diseased apple roots from the Waikato were in 1895 forwarded to Kew for examination, and were by Massee provisionally determined as being infected with the fungus *Dematophora necatrix* Hedw., a European fungus causing a root-rot of fruit-trees, vines and forest trees. Only mycelium was present on these specimens but Massee placed them in sterilised leaf-mould and claimed to have obtained at the end of three months, minute sclerotia, bearing conidiophores and conidia. Later in the same year a collection of New Zealand fungi was forwarded by Colenso to Kew, and among these specimens were fructifications of a *Rosellinia*, collected at Rotorua from the base of a fallen and decayed apple tree. Massee *(205)* found this to be an undescribed species, which he named *R. radiciperda*. He claimed that it was the perfect stage of the fungus he obtained from the apple roots sent from the Waikato, for he stated that among the fructifications of the perfect stage were sclerotia bearing conidiophores and conidia identical with those obtained in his experiments with the apple roots. Lending a certain amount of support to his claim is the fact that several species of *Rosellinia* occurring in Europe possess mycelium and conidia similar to those described by Massee. Evidence to the contrary is supplied by the following facts:—The author has treated roots infected with root-fungus to various processes with a view to inducing perithecial formation, but has invariably failed. Roots have been planted in boxes of soil, placed under old sacking, in long grass, exposed to the air, and in all cases failure has resulted, even although some of the experiments have been maintained for five years. Pure cultures have been obtained from infected roots, but although a luxuriant mycelial growth was obtained, no perithecia ever appeared. On a few cultures sclerotia were obtained. These were subjected to various treatments, but only mycelium was produced. Finally, at the author's request, Dr. Butler, Imperial Bureau of Mycology, examined Massee's type specimens, now at Kew, with a view to finding the conidial stages that Massee described as being present. He reported: "There is no trace of any secondary fructification on the type, and the hyphae below the perithecia form a thin crust and do not show the pear-

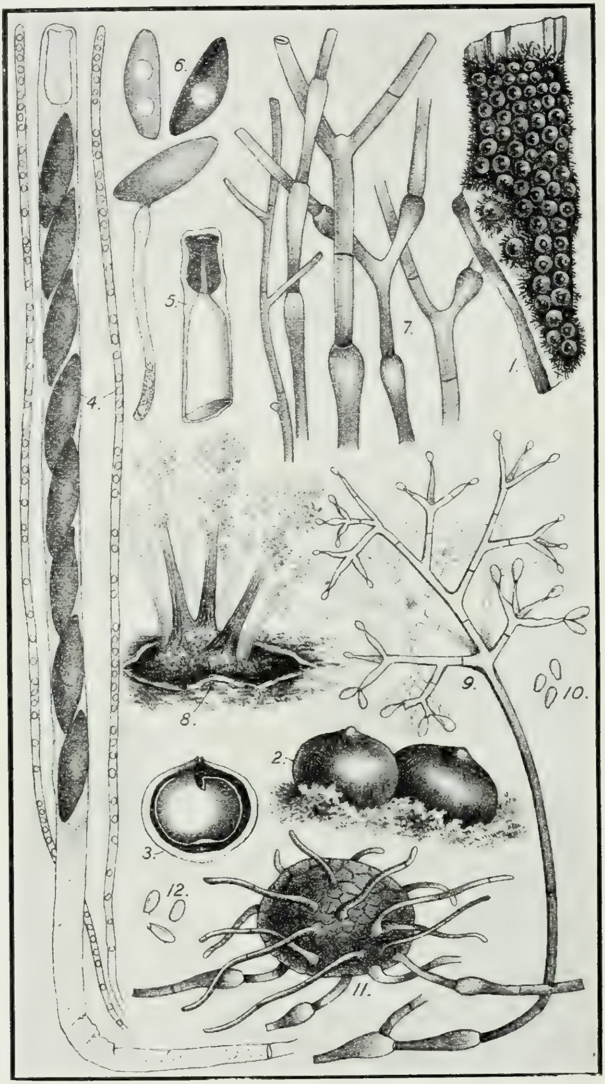


Fig. 75. ROSELLINIA RADICIPERDA.

1. Perithecia, nat. size; 2. perithecia, enlarged; 4. ascus and paraphyses, × 400; 6. ascospores, × 650; 7. brown mycelium with pear-shaped swellings, × 500; 8. sclerotium bearing fascicles of conidia, × 50; 9. conidiophore bearing conidia, × 400; 11. pycnidium, enlarged.

After Massee (205).

shaped swellings figured by Massee. I take it that the latter were associated with the earlier specimens of sterile and conidial stages, which I cannot find at Kew."

Thus it would appear that there is no satisfactory evidence for linking up the root-fungus prevalent in New Zealand with the species of *Rosellinia* described by Massee. Notwithstanding this, the author has maintained Massee's name for the causal organism, until such time as the matter is thoroughly cleared up, for by so doing any unnecessary name changing is avoided.

The mycelium of the fungus spreads from infected roots remaining in the soil until it comes in contact with the healthy roots of some congenial host. These the hyphae penetrate—apparently directly—and kill, spreading to the larger roots and finally to the crown, killing the roots as they advance. Finally, the cortex of the killed root becomes permeated with the hyphae; these are for the most part colourless, but where they approach the surface of the ground or appear on portions exposed to the air, they become coloured olive-brown. Under the microscope these coloured hyphae are seen to be septate, and possess in the vicinity of the septa, peculiar pear-shaped swellings, structures so characteristic as to serve as a diagnostic character whereby root-fungus may be separated from other soil-fungi attacking the roots of various plants. This character is present also in European root-rot, a disease which appears to resemble the New Zealand one closely in all but the ascigerous characters.

The hyphae within the killed tissues here and there become aggregated into compact sclerotia. The mycelium, conidiophores, and sclerotia are the only stages of this fungus that the author has ever succeeded in finding.

According to Massee *(205)*, whose plate is reproduced, the following fructifications occur in the cycle of this species, but as they appear to play little if any part in the perpetuation of the organism, they will receive but brief mention. The sclerotia, should infected roots bearing them be exposed to the air, give rise to fascicles of conidiophores (Fig. 75, 8), which are much branched at their distal ends. From the ultimate branchlets thus produced conidia are abstricted (Fig. 75, 9). Among the sclerotia on the surface of the root, embedded in the coloured mycelium, may be present small subglobose pycnidia, containing small colourless conidia (Fig. 75). Thus conidia may be produced in two different ways; they germinate readily in water, giving rise to colourless hyphae. Finally, at ground level of the bases of trees that have been killed for some time are produced fructifications of the *Rosellinia* stage. These consist of small, black, papillate perithecia, densely crowded on a dark-coloured mycelial crust (Fig. 75). Each perithecium contains numerous cylindrical asci, and each ascus contains eight continuous, fusiform, dark-coloured ascospores (Fig. 75).

Owing to the rarity of these spore stages it is improbable that they play any part in the perpetuation of the fungus. On the contrary, field investigations show that infection invariably occurs from some determinable source, such as dead roots or stumps impregnated with mycelium, which are invariably found to be present in the vicinity. So we may assume that the hyphae grow out from these points of infection until they come in contact with some suitable host, when they penetrate the roots and set up the conditions described above.

This is in part borne out by the fact that in no instance has root-fungus been found to be present in a locality that has not previously been in forest or scrub, save in one or two localities in the South Island, but in these latter instances the origin of the disease has always been traced to nursery stock obtained from the North Island, from nurseries known to the author to possess areas in which the disease is prevalent.

The disease may remain quiescent for many years in a locality ere it becomes noticeable on account of its effects on trees planted in that region. In such cases it is probable that the sclerotia are the means whereby it is able to persist in the soil, for these structures, in related fungi, have been known to remain viable for as long as twelve years, and at the end of that period germinate and produce a mycelium capable of infecting a suitable host.

CONSIDERATIONS REGARDING REMEDIAL TREATMENT.

It must be admitted that there is no known means of combating this and related soil-fungi, for of all the suggestions made in the literature dealing with this group, not one has stood the test of direct experiment. There is a greater need for research into the life-histories and remedial treatment of this group of diseases than almost any other.

In Germany, where a similar disease is prevalent in certain forest plantations, small infection zones are isolated by digging a trench, about 1 m. deep, around the zone, all soil being thrown to the inside. This prevents the outward spread of the mycelium and confines it to the interior of the infected region. This method would be impracticable under orchard conditions, for as a rule the zones are irregular in size and shape (that is, they are not apparent on the surface, but their presence is indicated only when trees are attacked), and frequently appear as numerous isolated areas. Trenches would not only prove costly to maintain—for they would have to be kept continuously open for many years, but would greatly interfere with cultural operations.

A second method, used in France against a similar disease of the vine, is to expose the crown and larger roots to the action of the atmosphere, and to dust them at frequent intervals with sulphur. This method has been tried out against root-fungus, but with little or no beneficial result. As all parts of the roots are infected, the fungus spreading from the smaller to the larger roots, it follows that the tree is invariably too far gone by the time the disease is noticeable on the larger roots and the crown.

In France a third method—that of applying chemical substances, toxic to fungi, to the soil—has received a considerable amount of attention. The following substances have been experimented with:—Calcium sulphite, carbon disulphide, copper sulphate, iron sulphate, quick-lime, potassium sulphate and potassium sulphocarbonate (51). Certain of these, notably carbon disulphide and copper sulphate, have given quite good results, but in New Zealand have been unsuccessful in combating root-fungus.

It is stated that the disease is prevalent only in poorly drained soils, and draining has been recommended as a preventive measure. Unfortunately, this is not the case in New Zealand, for the disease is more prevalent in the light, well-drained pumice soils of the Auckland province than in any other locality.

It has been found that peaches, when planted in areas where apples and pears have succumbed, have often proved resistant; but the peach is not entirely so, since in certain localities one frequently finds that peach trees are as severely infected as are apples and pears.

SUGGESTED REMEDIAL TREATMENT.

(a) Remove and destroy all infected trees, for it is well to remember that *infected trees do not recover*. Be careful to remove all roots and portions of decaying wood from the ground.

(b) Refrain from planting in those areas from which diseased trees have been removed. The areas thus abandoned may be utilised for vegetable culture, as intense culture would tend to destroy the fungus, soil fungi generally being intolerant of aerated soils. This period of abstention would necessarily be one of several years owing to the fact that the fungus may persist in the soil for an indefinite period.

(c) Avoid planting young orchards in those areas known to be infected with root-fungus, or areas which have previously been in forest or heavy scrub. This applies only to the North Island.

(d) In citrus-growing regions re-plant with citrus varieties since these are not known to be attacked.

SUMMARY.

1. Root-fungus is an endemic disease attacking the roots and crowns of pome- and stone-fruits and numerous other trees. It appears to be confined to woody plants.

2. The name of the causal organism is given here as *Rosellinia radiciperda,* a name subject to alteration.

3. The causal organism is a soil fungus; it spreads by means of mycelium, which ramifies through the soil and infects the roots of congenial hosts.

4. It is capable of remaining viable in the soil for an indefinite period (or in old pieces of wood), probably in the form of sclerotia.

5. No efficient method of control is known.

For literature references regarding this disease, see bibliography, p. 349, numbers *51, 205, 326.*

SILVER-LEAF, Stereum purpureum Pers., ex Fries.

This disease is discussed fully under stone-fruits, p. 284, so that brief mention only will be made here as to its prevalence on pome-fruit trees.

In New Zealand it has been found on apple, pear and quince, but is extremely rare on the latter two hosts. In general its appearance on pome-fruit trees is similar to that on stone-fruit trees, the presence of the organism being marked by a peculiar silvering of the leaf so characteristic of this disease. But the silvering of the leaf is not an infallible sign of its presence, for on occasion are seen trees killed by the fungus and covered with the fructifications yet death was not preceded by noticeable silvering.

On pears and quinces the disease is so rare as to be negligible, but on apples it is not uncommon, especially in those areas where trees have been cut back and regrafted, and the wounds so made left untreated with a protective covering. Frequently, too, with this host, trees are found showing signs of silvering of the leaves, yet in a few seasons, during which they have made normal growth, they have apparently recovered. This is a condition often noticed on trees cut back for regrafting, and has led to a belief among orchardists (often cited when the necessity for taking steps to counteract the effects of this disease is being stressed) that the silvering is due to the injury caused to the tree through cutting away large branches, and is not a pathogenic condition.

CHAPTER XVI.
POME-FRUIT DISEASES.
(Continued.)

(*a*) ***Fungous Diseases.***—Concluded.

SOFT AND STORAGE ROTS.

In the packing shed, in transit, in market and in cool-stores certain soft-rots prevail. These take an annual toll that amounts to more than 15% of the total output. In fact, it is impossible to give any accurate idea as to the amount of damage caused by all soft and storage rots. But it may be stated that almost without exception any apple, pear or quince (stone-fruit rots are dealt with on p. 294; citrus fruit-rots on p. 335) that has had the epidermis damaged or punctured is more likely to be culled because of infection with a soft-rot than it is to reach the market.

Approximately 383,500 bushels of apples and 60,058 bushels of pears were held in cool-store throughout New Zealand in 1923; in addition to this about 194,400 bushels of apples and 32,000 bushels of pears were held in packing sheds or in the orchard, a total of approximately 669,950 bushels in all. It is safe to conclude from the foregoing particulars that over £25,000 worth of this fruit was rendered unmarketable by one or other of the following soft-rots.

(*a*) BITTER-ROT, Glomerella cingulata (Stonemn.) Sp. et v. Schr.

This disease is dealt with in detail on p. 110, but as it is one of the causes of a serious storage loss, it is again briefly discussed under this heading. It occurs principally on fruit stored in the packing sheds prior to grading and packing, and also on fruits stored in open sheds or in the orchard. Although present in cool-store, the damage it causes is not then so great, for it would appear that the low temperature of a cool-store tends to hold it in check.

Unlike blue-mould this disease may penetrate directly through the epidermis, so that one or two diseased apples are capable of infecting all the fruit in a case, given suitable conditions of temperature and moisture. Thus in order to minimise loss from this disease, it is necessary to go over at intervals all fruit held in store, and remove any showing signs of infection.

It is difficult to calculate the losses due to this disease, owing to the variations in percentages of infection in the different stores, for in some the losses are high, in others, low; but from actual figures obtained from stores in 1923, it is estimated that it caused the loss of quite 2% of the fruit.

(b) BLACK-ROT, Physalospora Cydoniae Arnaud.

This disease is discussed in detail on p. 118.

Infected fruits are so characteristic as to be determined readily when encountered, and are liable to confusion only with brown-rot. Fortunately the losses due to this disease are slight, for in New Zealand it is confined to those fruits that have been damaged by punctures due to codlin-moth or other agency.

(c) BLUE-MOULD, Penicillium expansum Thom *(302)*.

Syn.: *Penicillium crustaceum* Fr.; *P. glaucum* Link,
p.p.; P. glaucum Bref.
Bin-rot; penicillium-rot; soft-rot.

This is the most destructive of all rots occurring on fruit in store, in the markets or in cool-store. It is world wide in its distribution, and may be found on various substrata in addition to pome- and stone-fruits. In order to appreciate the losses caused by this disease, the following figures are given: In 1919, out of 2,973 carloads of apples examined by inspectors of the United States Bureau of Markets, 23.7% of this fruit was found to be infected with blue-mould; in 1920, 3,462 carloads examined were found to contain 60.6% of fruit infected with blue-mould *(146)*.

APPEARANCE ON THE FRUITS.

The disease first appears in the form of a light-coloured spot, which is watery in appearance and quite soft to the touch. It is of a pallid brown colour and is sharply marked off from the healthy part of the fruit by a clear-cut margin (Fig. 76). The spot increases rapidly in size until within a few days the whole fruit is completely decayed, appearing as a soft watery mass. Over the diseased portion, within a short time after infection, appear isolated tufts, the fructifications of the causal organism. These are at first pallid green or even white, but soon change to a dull blue-green. Fruits infected with blue-mould readily are recognised by the unpleasant "mouldy" smell which they give off. Then, too, the taste of infected tissue is decidedly unpleasant, and is noticeable even on the flesh of a healthy apple that has been in contact with a diseased specimen, or has been peeled with a knife previously used in cutting into a diseased fruit.

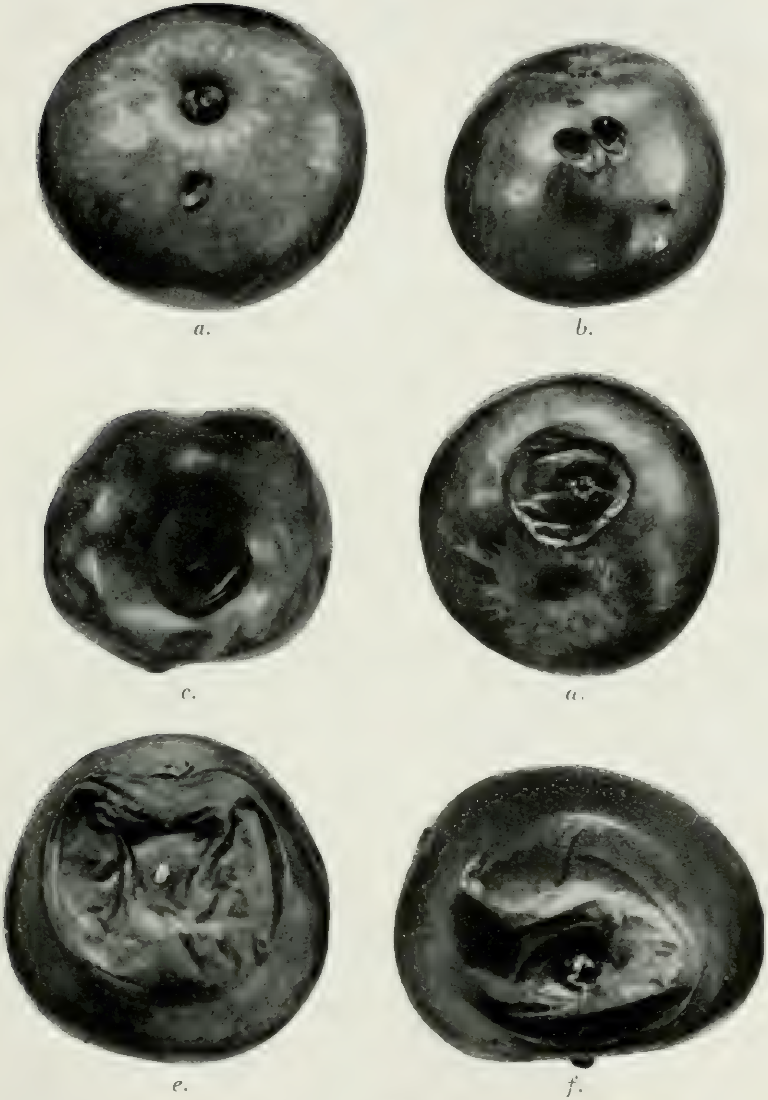


Fig. 76. BLUE-MOULD FOLLOWING SKIN INJURIES. × ½.

These six specimens were taken from one case of apples held in cool-store pending shipment. Note that in all cases rot has commenced in the vicinity of skin injuries.

Photos. H. Drake.

The external symptoms described above are the usual manifestation of this disease, but occasionally on varieties with a large "eye," the centre of the fruit is found to be rotted, the exterior being quite healthy.

Careful examination of infected fruits shows that without exception infection has taken place through some injured portion of the fruit, for the causal organism is unable to penetrate through the healthy epidermis, although it has recently been shown that it may on occasion penetrate through the attached stem *(32)*, especially if this happens to be at all fleshy.

This rot is not confined to the store, market or household, for it regularly occurs in cool-store, even at the low temperatures experienced therein; but under such conditions the rot does not present the same watery appearance.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

The fungus is saprophytic on numerous substrata, and as it produces conidia throughout the year it follows that spores are present in the atmosphere in abundance. This is especially true of the atmosphere in the vicinity of packing sheds, fruit shops, etc., for invariably infected fruits in various stages of decay are to be found in the precincts of these places.

Should a spore alight on the injured surface of a fruit it germinates and produces a hypha which penetrates into the tissues, where it branches repeatedly to form a mycelium, the hyphae of which penetrate between the cells, penetration being facilitated by the secretion from the tips of the hyphae of a substance which has a solvent effect upon the middle lamella. Hyphae also penetrate into the cells, killing them in advance, so that in a short time after penetration of the tissues has been effected, a discoloured zone of dead cells appears in the vicinity of the injured area. In the course of a few days small masses of hyphae are produced through the now dead epidermis, and, from the free surfaces of these masses, arise numerous upright conidiophores (Fig. 77). These are much branched at their free ends, and from the tips of the ultimate branches chains of small, colourless globose conidia are produced, which are readily detached and carried by the wind for long distances. No other spore stage is known to occur in the cycle of this species.

REMEDIAL TREATMENT.

As the fungus is able to infect fruits only through some skin injury, it follows that infection in cool-store or in ordinary store, would be reduced were a system adopted of rigorous culling of all fruit showing signs of skin injury. Examination of innumerable infected fruits shows that usually these injuries are due to careless handling

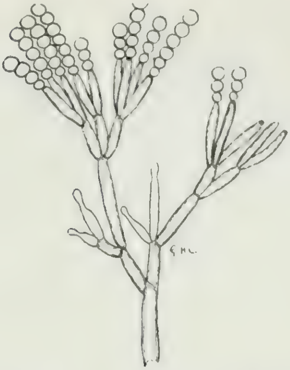


Fig. 77. CONIDIOPHORE OF PENICILLIUM EXPANSUM. × 300.
Showing conidiophores and chains of conidia.
Original.

of the fruit during picking, packing and marketing. Stem-end punctures, finger-nail scratches, case nail punctures, bruises, codlin-moth perforations, bronze-beetle injuries, as well as skin injuries caused by black-spot, blister-disease, etc., are all points of entry for this organism. Spray treatment is worthless, for no spray treatment of fruit on the trees will counteract injuries caused through subsequent careless handling.

Thus the only remedial treatment lies in the prevention of skin injuries. This necessitates a minimum of handling during picking and packing, a subject discussed on p. 95. Another fruitful source of injury is during grading operations, especially with certain of the graders now in use. The grader should so be adjusted that no fruit falls upon another, or rolls so as to come into violent contact with another, or with its stem. In packing, apples frequently are forced upon one another, with the result that the stem of one perforates the epidermis of another. In wrapping for export the fruits should be wrapped and packed in such a manner that the pad of the wrapping paper is placed so as to act as a cushion, and thus reduce the danger of bruising. In packing for export all fruits showing any signs of skin injury, or blemish, should be excluded, for such fruits will invariably be found in a rotted condition when the case is opened in the export markets. It may be mentioned here that rotted fruits of this nature, although in contiguity with healthy fruits in the same case, are incapable of infecting the latter, provided these are undamaged.

SUMMARY.

1. Blue-mould is a storage- and transit-rot of fruits. It is able to infect only through skin injuries.

2. The causal organism is *Penicillium expansum,* a fungus world wide in its distribution.

3. As it infects fruits through skin injuries it follows that the only method of minimising infection is to handle fruits in such a manner that skin injuries, due to careless handling, are eliminated.

4. It is imperative that for export purposes all fruits showing any signs of skin injuries be rejected, for these invariably will develop blue-mould before they reach the markets.

For literature references regarding this disease, see bibliography, p. 349, numbers *32, 146, 162, 201, 302.*

(*d*) BOTRYTIS-ROT, Botrytis cinerea Persoon.

Under this heading are probably included many races, identical morphologically, but differing greatly in their powers of infection and cultural characters. For in a series of cultures made by the author from various specimens of rotted apples taken from stores, numerous strains have appeared, some parasitic, others weakly so, others apparently saprophytic, but all producing fructifications identical morphologically with one another.

One strain in particular is the cause of a firm brown rot of apples, and is the only one of sufficient importance to be discussed here. Infection occurs through the "eye" of the apple, for when a suspension of spores in distilled water was placed therein a percentage of the fruits thus treated became infected, whereas when the spore suspension was placed on the uninjured epidermis no infection resulted. If the epidermis was first injured and the spore suspension placed in the wound, infection readily occurred. As only a small percentage of infection was obtained when spores were inoculated into the "eye" it would appear that either the organism was a weak parasite, or what is more probable, merely a wound parasite, the "eye" in those cases where infection resulted being slightly damaged. It is worthy of remark that the epidermis of the fruit is protected with a waxy layer, the cuticle, but this covering is absent in the "eye," its place being taken by a layer of corky tissue.

APPEARANCE ON THE HOST.

The first sign of infection is a discoloured soft area around the "eye" of the fruit (Fig. 78). This area spreads in unequal fashion so that one side of the fruit, usually the more highly coloured side, becomes first infected. Little alteration in the shape of the fruit occurs, for the infected area remains firm; it becomes a light brown, and the epidermis frequently is thrown into slight ridges or folds, and is readily removed from the diseased flesh on slight pressure being exerted (Fig. 79).

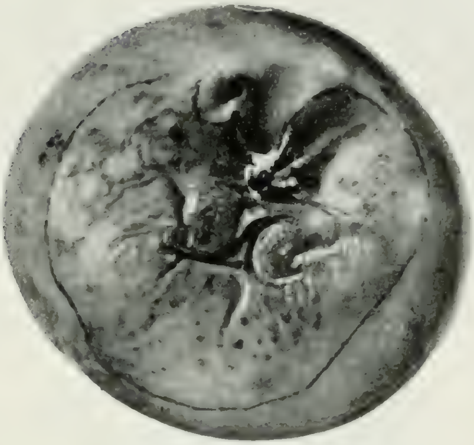


Fig. 78. BOTRYTIS-ROT. × ¾.

This fruit was artificially infected, spores being placed in the calyx. Infected zone is outlined in ink.

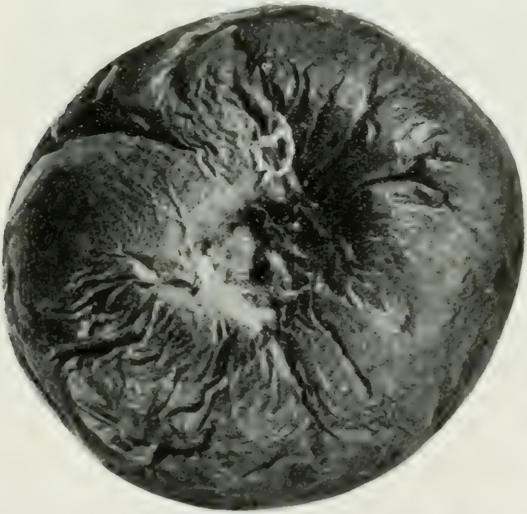


Fig. 79. BOTRYTIS-ROT. Natural size.

Later stage, showing complete decay of the fruit. Fructifications are present in the region of the calyx.

Photos, H. Drake.

Fructifications of the fungus appear only where the epidermis has been broken, appearing as an ashy-grey mould. Under the microscope this is seen to consist of numerous dark-coloured upright conidiophores, each bearing several lateral branches, on the ends of which are numerous minute globose conidia. (Fig. 80.)

Fortunately this disease is not prevalent, for infected fruits have been forwarded from only one or two provinces. It is not confined to the store, for three years ago fruits infected with an eye-rot were forwarded to the laboratory from Nelson. From these R. Waters isolated a species of *Botrytis* morphologically and culturally identical with the one under discussion.

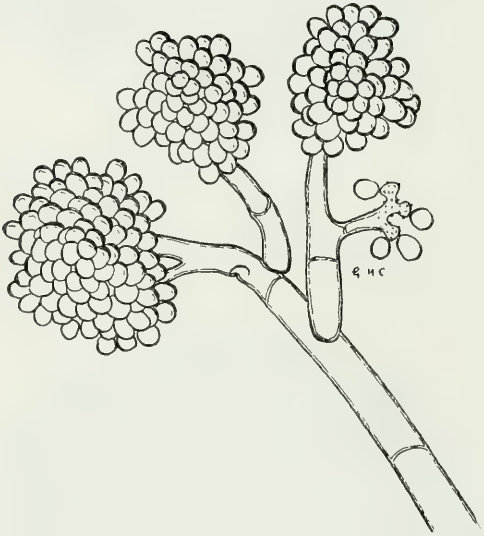


Fig. 80. FRUCTIFICATIONS OF BOTRYTIS CINEREA. × 300.
Original.

As it will not infect fruits other than through the "eye" or through skin injury, it is improbable that it would spread by contact to healthy fruits in the case, nevertheless it would be advisable to go through fruits in storage, at stated intervals, and cull any showing signs of infection.

(e) BROWN-ROT, Sclerotinia cinerea Schroet.

This disease is discussed in detail on p. 228. Occasionally it infects apples, causing a rot similar in appearance to that due to black-rot. Fortunately it is rare on stored fruits, and appears to infect only those that have been injured in some manner.

(f) DELICIOUS-SPOT (Fungus undet.).

An apple-rot common on the variety Delicious proved troublesome in cool-store during 1923, one line of several hundred cases being affected. Of these six cases were examined in detail at the end of August, and as many as 60% were not fit to repack for the market on account of this trouble. In 1924 it again became noticeable, especially on the varieties Delicious and Docherty.

The disease first appears in the form of a minute chocolate-coloured spot, 0.5 mm. in diameter, slightly depressed but scarcely penetrating below the epidermis. By the time it has attained a diameter of 1 mm. the centre is light-brown to yellow, and is surrounded by a chocolate-coloured border. Spots of all sizes up to 5 cm. in diameter are found, the width of the darker coloured border being about 1-6th that of the diameter (Fig. 81). Spots invariably are circular in outline, save where they coalesce. Infected tissues become light brown and spongy, and the rot eventually extends to the core.

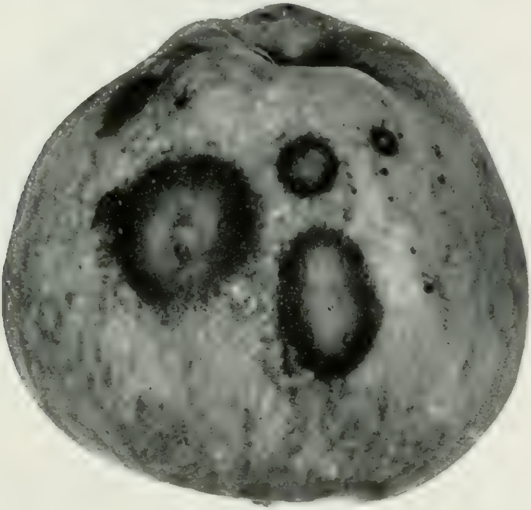


Fig. 81. DELICIOUS-SPOT. × $\frac{2}{3}$.
Note different stages of infection.

Photo, H. Drake.

This is essentially a cool-store rot, for it has not been found on fruits in the orchard or in ordinary store. It would appear to be enhanced by long storage.

It is suggested that the fruit be gone through periodically, and whenever the disease appears, it would be advisable to release the line before serious loss from this trouble ensues.

FLESH-COLLAPSE.

See under physiological diseases, p. 205.

(g) PINK-ROT, Trichothecium roseum Link.

Syn.: *Cephalothecium roseum* (Fr.) Cda.

This is a minor disease of the apple, pear and quince. In New Zealand it is usually found only on stored apples, and then only when the fruits have previously been infected with black-spot. Elsewhere it on occasion attacks the fruit whilst on the tree, but is able to penetrate the tissues only through skin injury. It is characterised by the appearance of a white woolly growth over the surface of the black-spot lesion (Fig. 82). After a time the black-spot lesion sinks slightly below the surface of the fruit, due to the fact that the pink-rot organism has destroyed the tissues beneath.

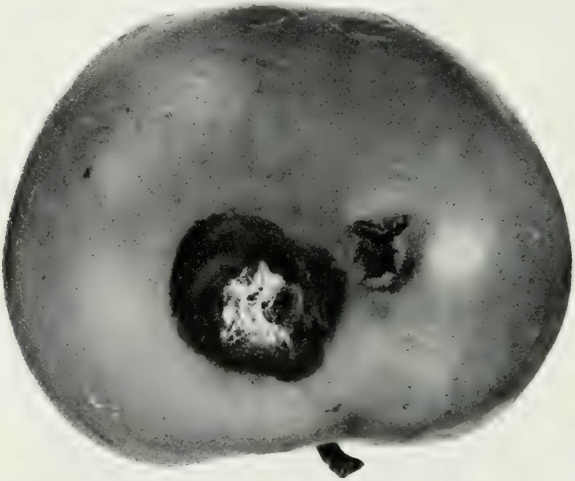


Fig. 82. PINK-ROT ON APPLE FRUIT. Natural size. Penetration has been effected through a black-spot lesion.

Photo, H. Drake.

Fortunately with us it is so rare as to prove negligible, consequently to combat it no special precautionary measures need be adopted. Should it prove at all troublesome it would be advisable to cull any fruits showing black-spot lesions from a line that is to be held in store for any length of time, for as has been shown above it is able to infect through these or similar lesions. (See also under mouldy-core, p. 214).

(h) RHIZOPUS-ROT, Rhizopus nigricans Ehr.

Occasionally this is found on pome-fruits in store, but does not affect them to the extent that it does stone-fruits. The disease is discussed more fully under stone-fruits, p. 296.

SCALD.

See apple-scald under physiological diseases, p. 197.

Several other fungi have been isolated from rotted fruits taken from cool-store, but as the damage caused by them is negligible it will not be necessary to discuss them further.

From the foregoing it becomes apparent in practically every instance that soft and storage rots gain entry to the tissues of the fruit through skin injuries. This is significant and should point to the necessity of carefully picking over all fruits before placing in store, and culling all blemished fruit of any description. These could be placed on the market, or preferably, sent to the factory. The reward for careless handling is a high percentage of rejects through these storage rots, for even at a low estimate (15%), 100,000 bushels of apples and pears were in 1923 lost through storage rots!

Certain storage rots may be used as indicators of maturity or over maturity of the stored fruit, a fact brought to the author's notice whilst in England in 1924, by Dr. A. S. Horne, Imperial College of Science and Technology. Dr. Horne found in the course of his work on apple storage rots that certain apples with a relatively high acidity or hydrogen ion concentration are comparatively immune at maturity from the attacks of certain fungi; after long storage, during which period there is a fall in hydrogen ion concentration (the fruit becoming less acid) such apples become susceptible to attack from certain species of fungi. Again, he found that a succession of storage rots occurs throughout the period fruits are kept in cool-store; one species making its appearance shortly after the fruits have been placed in store; another after storage for some time; and a third only after long storage. This characteristic of different fungi may be due to the presence or absence in the fruit at certain periods of storage, of sugars, pectic substances, mineral salts, available nitrogen or the degree of hydrogen ion concentration. Were this matter fully worked out, it may be possible by the incidence of certain fungi to determine the period when unloading of certain varieties should commence. This has already been indicated in the case of Delicious-spot.

VALSA-INJURY, Valsa leucostoma (Pers.) Fr.

For a detailed account of this disease, see under stone-fruits, p. 298. It is uncommon on pome-fruit trees, but was found to be present on numerous trees in Central Otago in 1919.

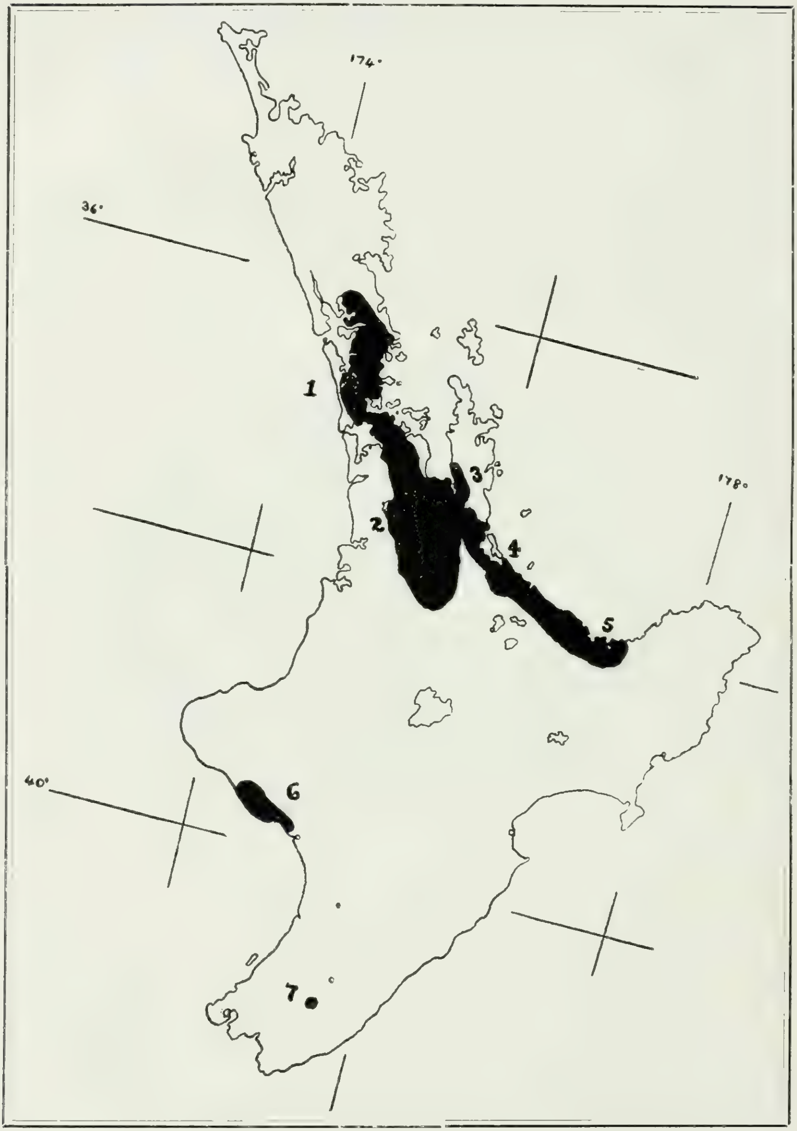


Fig. 83. MAP SHOWING FIRE-BLIGHT DISTRIBUTION (in black).

1. North Auckland; 2. Waikato; 3. Thames; 4. Tauranga; 5. Opotiki; 6. Whanganui; 7. Greytown fire-blight areas.

Original.

CHAPTER XVII.

POME-FRUIT DISEASES.

(Continued.)

(b) Bacterial Diseases.

FIRE-BLIGHT, Erwinia amylovora (Burr.) Committee S.A.B. *(39)*

Syn.: *Micrococcus amylovorus* Burr.; *Bacillus amylovorus* (Burr.) Trev.

Blight-canker; blossom-blight; collar-blight; fruit-blight; pear-blight; root-rot; twig-blight.

The most destructive disease of pome fruit-trees in North America is fire-blight; and in New Zealand it has shown that, given suitable conditions, it would prove equally destructive. It has been known to occur in North America for at least 100 years, and has been recorded in addition from Japan *(172)*.

In New Zealand it was first noticed in December, 1919, but the nature of the disease was not proven until early in 1920, when it was isolated and cultured by Waters *(96)*. It appeared simultaneously in several widely separated localities in the Auckland province; for in investigating the disease in the field early in 1920 the author found it to be present in Warkworth and Te Papa (Fig. 83, *dist. 1*), Hamilton, Cambridge and Te Awamutu (Fig. 83, *dist. 2*), Tauranga (Fig. 83, *dist. 4*), and Opotiki (Fig. 83, *dist. 5*); within eighteen months it had spread until it was found to be present in practically the whole of the area coloured black on the map (Fig. 83). A more detailed discussion of its distribution in this area is given on p. 57. In 1922 an outbreak was recorded in the Whanganui district (Fig. 83, *dist. 6*), and later in the same year it was found to be present in the Wairarapa (Fig. 83, *dist. 7*). Fortunately this last infection occurred only on two trees.

Its introduction into New Zealand is shrouded in mystery, as is its introduction into the Whanganui and Wairarapa districts; numerous theories have been propounded to account for its appearance in the Dominion and in these two localities, but no evidence has been brought forward in support.

For explanation of terms, see glossary, p. xi.

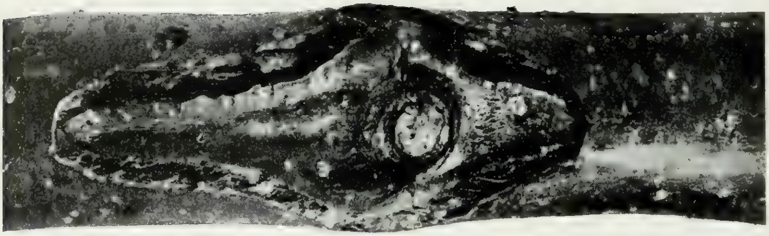


Fig. 84. FIRE-BLIGHT CANKER ON PEAR BRANCH. × ¼.

In the centre is the stump of the shoot down which the organism spread and gained entry to the branch.

Photo, E. Bruce Levy.

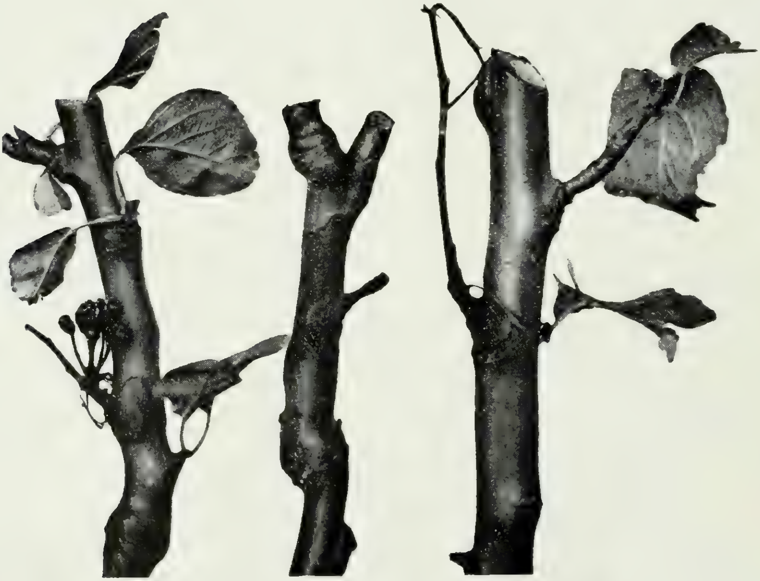


Fig. 85. FIRE-BLIGHT ON APPLE BRANCHES. × ⅓.

Blossom infection on the left and in the centre; shoot infection on the right. Note the cankers at the base of the dead shoot and spurs. Black-rot has followed the fire-blight injury.

Photo, Brett Co.

In the Dominion this pathogen has been isolated from apple, hawthorn, medlar, pear and quince *(320)*, but it is not confined to these hosts, for in North America it has been recorded in addition on the following *(291)*:

Apricot	*(Prunus armeniaca).*
Cherry	*(Prunus Cerasus) (166).*
Cheney plum..	*(Prunus americana* var. *nigra).*
Cultivated crab	*(Pirus Malus* var. *acerba).*
Hawthorn ..	*(Crataegus Oxyacantha; C. pyracantha).*
Prune	*(Prunus domestica).*
	(Prunus triloba var. *plena).*
Service berry..	*(Amelanchier canadensis).*
Strawberry ..	*(Fragaria vesca;* not found on this host in nature)
Wild crab ..	*(Pirus coronaria).*

APPEARANCE ON THE HOSTS.

Fireblight infects blossoms, fruits, shoots, and branches. The first signs of infection occur at blossoming time, when as a result of infection the young fruits change colour, becoming discoloured brown or black. Blossom wilt is usually followed by wilt of the leaves on the blossom spur, for the disease passes through the blossom to the spur, travelling down the pedicel. If the blossom happens to be on a lateral the disease usually spreads to and girdles it, causing it to wilt and die. On such laterals the leaves do not fall but turn brown and remain hanging on the tree, and if these infected laterals are at all numerous, they give to the tree its characteristic appearance as of having been scorched with fire, hence the name fire-blight.

Should the blossom spurs be situated on larger branches infection of these branches may occur (Fig. 85). Finally large cankers may be formed on the main branches. These usually are characteristic in that the bark is darker in colour than the normal, and becomes slightly sunken, but is not broken up into smaller areas by the appearance of numerous crevices, as is the case with black-rot or diplodia-canker. Later it becomes delimited from the healthy tissues by the appearance of a sharply defined crevice which outlines the cankered area. (Fig. 86).

On fruits the disease produces a soft-rot, similar in appearance to numerous other soft-rots, save that numerous globules of ooze are seen to be present, scattered over the surface.

In the spring, especially on hawthorn and pear, these cankers present a water-soaked appearance, and frequently exude coloured drops of ooze. In New Zealand pears have been most severely infected, for usually infection is followed by death of the greater part of the tree, and in many instances the tree is killed outright.

On apple trees only blossom and lateral infection is prevalent as a rule, for branch canker is an unusual condition, the spread of the disease ceasing when the larger branches are reached.

ECONOMIC IMPORTANCE.

It has been shown that the disease may infect and destroy blossoms, fruits, branches and even entire trees; hence infection may result in the loss of part or the whole of the crop through injury to the fruit, or may kill branches and laterals, thus reducing the crop; or may kill the tree outright, resulting in the total loss of the crop, and, what is more important, the total loss of the tree.

Some indications of the serious nature of this disease may be gained from the following particulars. In Tauranga early in 1920 the author saw a block of 10 acres of pears which had been practically killed outright in a few weeks, the remaining trees being damaged to such an extent as to render them worthless.

The economic effect of such a disease is a far reaching one, for its presence in the North Island has caused an embargo against the shipping of fruit-trees to be placed on certain localities, and has caused the Australian authorities to close their ports to nursery stock grown in New Zealand.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Fire-blight is a bacterial disease caused by *Erwinia amylovora.* The organism winters over in cankers formed on large branches of the apple, pear, and hawthorn, for Waters *(96)* has definitely proved that it is able to overwinter in cankers on this last host. In the spring small masses of ooze exude from these cankers; this is at first fluid, but later it may dry to a stiff resinous mass, amber in colour, or may harden off in dry weather to a smooth reddish solid, that reliquefies with moisture. Within the mass of ooze are countless numbers of the organism, each theoretically capable of causing infection. The same worker *(319)* has shown that the organism is capable of living in this dried exudate for nine months, and has also shown that it may cause infection after immersion in distilled water for two months. The appearance of the ooze coincides with the blossoming period of the apple, pear and hawthorn. It appears to attract insects which visit the ooze and carry away with them, attached to various parts of their bodies, large numbers of the organism. Many different insects have been shown to be carriers of the organism from ooze to the blossoms or young shoots, a matter first experimentally proved by Waite *(312), (313).* Among these may be enumerated honey-bees, aphids, leaf-hoppers, borers and sucking insects *(250).*

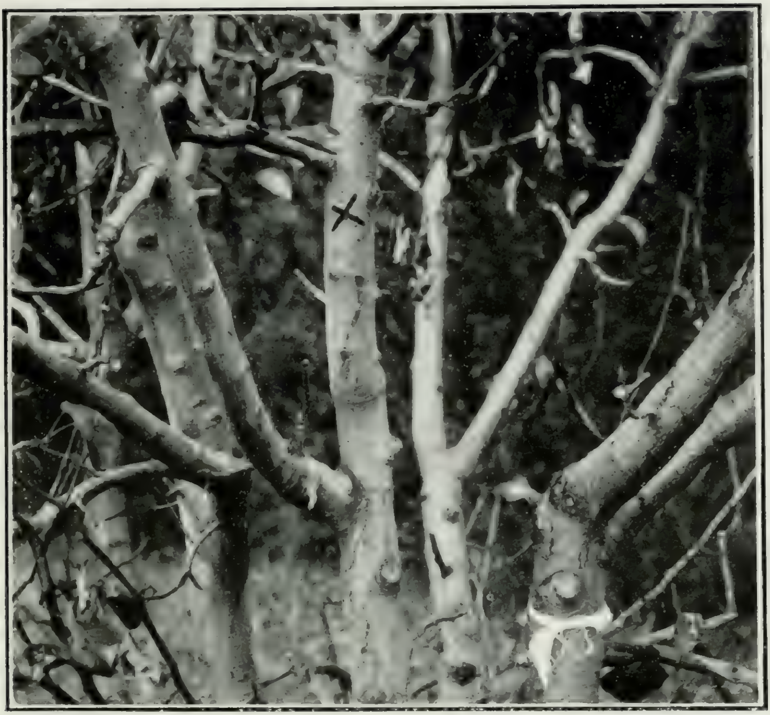


Fig. 86. FIRE-BLIGHT CANKERS ON THE MAIN LEADERS OF A PEAR TREE. × 1/10.
On the limb marked x is a typical canker.

Should such insects visit the blossoms, they may leave in the calyces organisms which are capable of reproduction in the nectar contained therein *(149)*. They may then penetrate into the tissues of the calyx and thence down the pedicel to the lateral or branch bearing the blossoms.

Sucking insects are able to carry the organism in their mouth parts *(320)* and should they puncture the succulent tissues of young shoots after having visited infected shoots, they are quite capable of causing infection; in fact the majority of shoot infections occur in this manner. The organisms then may spread to the larger branches and form the cankers already described. In these cankers they may remain in a quiescent condition until the following spring, when they begin to multiply rapidly, until such numbers are produced that they are forced out of the tissues, appearing on the surface of the canker embedded in the ooze, a substance formed partly from their own secretions, partly from host cell-sap. Insects visiting this ooze again spread the disease, and the cycle of infection recommences.

CONSIDERATIONS REGARDING CONTROL.

It has been shown that fire-blight overwinters in cankers formed on large branches of the apple, pear and hawthorn. Therefore it may justly be claimed that if these cankers were eliminated the disease would be exterminated. This would certainly be the case were the disease confined to orchard trees alone, for the growers themselves would realise the value of such work, even though it meant the destruction of all infected trees. For were this carried out for one season the disease would be stamped out.

Unfortunately extermination of the disease in New Zealand is practically impossible, for in the areas where it is now known to be present there are many hundreds of miles of hawthorn hedges, extending practically from one end of the Auckland province to the other. This host has proved highly susceptible to fire-blight, and many miles of hedges have been found to be infected. It is impossible to have these hedges exterminated as the cost would be prohibitive, and in certain localities where dairying is in vogue, they are too valuable an asset to be destroyed. The problem has been satisfactorily solved by the passing of the *Fire-blight Act* 1922 *(18)*, empowering the Governor-General to declare any specified district of New Zealand to be a commercial fruit-growing district, and to make regulations for the trimming or cutting down in the manner and at the times specified of all hawthorn growing within the declared district or any part thereof. The following districts have been declared to be commercial fruit-growing districts within the meaning of this Act:

Port Albert District.
Warkworth ,,
Waitemata ,,
Albany ,,
Te Kauwhata ,,
Thames ,,
Hawke's Bay ,,
Greytown District.
Waimea ,,
Marlborough ,,
Rangiora ,,
Christchurch.
Otago ,,

This regulation scarcely is likely to be enforced save in those districts where fire-blight is present, or imminent, but in these regions, if fruit-growing is to continue, then the destruction of hawthorn is imperative. In certain areas, as in the Waikato, where dairying is the principal rural industry, the hawthorn hedges are too valuable to be destroyed, consequently in such a locality it were simpler to destroy the pome-fruit orchards, and, it might be added, fire-blight has practically done this.

CONTROL.

In those districts in which fire-blight is present, the only satisfactory method of control would consist in the eradication of all hold-over cankers, thus preventing the production of the ooze from which the disease starts afresh in the spring.

A second method of control sometimes suggested, is the control of all insects, thus preventing transmission of the disease. This is not only impracticable (orchardists have been attempting to combat insects for 30-odd years with but indifferent success) but were such insects as honey-bees prevented from visiting orchards at blossoming time, it is probable that a considerably diminished crop would result, due to imperfect pollination.

A third measure is the planting of resistant varieties. Owing to the short length of time fire-blight has been in the Dominion, and to its erratic behaviour whilst here it is premature to express an opinion regarding this last.

Removal of cankers, in the case of fruit-trees, would frequently lead to destruction of large branches, so that a system of cutting out may be practised in its stead. But in dealing with cankers on small limbs, lateral and spur infection, it is advisable to cut out the whole branch, lateral or spur, cutting well into the healthy wood, the final cut to be made fully 30 cm. below the apparent infection.

It is manifestly impossible to cut out cankers in hawthorn hedges, as the work involved would be too costly and the time required too great, so that the only recourse is to total destruction. For this purpose the simplest and cheapest method would be to pull them bodily out of the ground, using a tractor, traction engine or team of horses for the purpose; for if cut back with an axe or slasher they again would give rise to shoots which would be liable to infection at any time, and furthermore would require to be cut back every second or third season.

It must be stressed that cutting out of cankered areas, or dressing of such wounds, must be thorough, for if one or two cankers are allowed to remain, they are capable of producing in the spring sufficient ooze to infect every tree in that district, or at least to serve as the centre of a fresh cycle of infection, from which other trees would become infected as the season progressed.

To treat cankers when it is desired to save the limb, with a sharp knife or drawknife (further particulars of this process are to be found on p. 36) cut out all diseased bark and wood, being careful to cut well into the healthy wood. Dress the wound smooth, then sterilise by swabbing it with a sponge soaked in the solution recommended on p. 36.

After the wound has been sterilised and has dried out it should be painted over with coal tar.

As there is danger of spreading the disease by using infected tools, all saws, secateurs, etc., used in these operations, should be sterilised by swabbing with formalin solution, 1 part to 50 parts of water.

SUMMARY.

1. Fire-blight is a bacterial disease attacking blossoms, fruits, shoots, branches and roots. It occurs in New Zealand on the apple, pear, quince, medlar and hawthorn, and in North America has been recorded on numerous additional hosts of the family Rosaceae.
2. The name of the causal organism is *Erwinia amylovora.*
3. It overwinters in large cankers on pear, apple and hawthorn and in the spring issues from the canker embedded in a viscid mass (ooze). It is carried to blossoms by insects.
4. Control measures consist in the eradication of the sources of infection, i.e., cankers and infected laterals and fruit-spurs.

For literature references regarding this disease see bibliography, p. 349, numbers *18, 29, 39, 70, 95, 96, 149, 172, 173, 250, 291, 312, 313, 319, 320, 322.*

ROOT-KNOT, Phytomonas tumefaciens (Sm. et Townsd.) Committee S.A.B. *(39).*

This disease frequently has been found on apple and pear trees introduced into the Dominion from Australia. The photograph on p. 305 well illustrates the characteristic appearance of the disease.

It cannot be claimed that the effects of this disease are serious, for although it has been known to be present in New Zealand for many years, yet it does not appear to affect detrimentally either yield or growth.

The disease is discussed in detail on p. 304.

CHAPTER XVIII.

POME-FRUIT DISEASES.

(Concluded.)

(c) Physiological Diseases, and Diseases of Unknown Cause.

APPLE-SCALD.

This is essentially a cool-store trouble. Apparently it has been known to occur in North America for the past 20 years, but in New Zealand has become noticeable only during the last three years. It appears to be confined to the fruit of the apple.

APPEARANCE AND EFFECT ON THE HOST.

The first appearance of apple-scald on the fruit is the presence of brown, discoloured areas on and under the epidermis. These areas are more or less elliptical in outline, and are at first but slightly depressed. As the trouble progresses the tissues beneath may become discoloured, this discolouration penetrating to a depth of 6 mm. or more. The surface may become more conspicuously depressed, when the infected area appears as a deep groove or hollow in the surface. This is coloured dark chestnut-brown, and is frequently bordered by a coloured margin. Apparently the disease is more common on the less coloured portions of the fruit, the highly coloured parts, especially of red apples, being less frequently affected.

ECONOMIC IMPORTANCE.

Where precautions are not taken for its prevention, apple-scald may become a serious cool-store trouble, for the diseased areas render the fruit unsightly, and, when at all well-marked, unsaleable. Further, the killed areas are readily penetrated by the numerous soft and storage rots which abound in cool-store. Thus fruits severely affected are seldom likely to reach the market.

CAUSE.

From the fact that they were able to produce artificially a condition apparently identical with scald by exposing the fruits to vapours of certain dilute esters (e.g., ethyl acetate, amyl acetate, methyl butyrate). Brooks, Cooley and Fisher *(59)* have assumed that scald is due to the accumulation of esters or similar products of the apple in the tissues of the fruit and in the surrounding air. This assumption is further supported by the fact that apples themselves are known to give off esters or related gases; that control measures based on this theory are successful, for they have found that ventilation prevents scald; that scald may be eliminated by wrapping fruits in paper permeated with certain fats and oils (olive oil, cocoa butter, vaseline, and beeswax were found to be the most efficient absorbents), substances which have a great absorbing power for these gases. Waxy apples do not scald as soon or as readily, the wax apparently serving as an absorbent of the harmful gases.

These fruit esters are volatile, and their rate of vapourisation is greatly increased by a rise in temperature, so it is not surprising to learn that scald does not occur in apples stored at temperatures over 25°C. (77°F.) for at such temperatures these volatile substances would readily escape. At low temperatures the gases are less volatile, and where ventilation is poor they accumulate in or near the skin of the apple in the vicinity of the lenticels, and there kill those cells with which they come in contact. Thus scald would be more prevalent on immature fruits, for the chemical changes which take place during the colouring of the fruit apparently produce a skin condition highly resistant to scald *(59)*.

CONTROL.

Brooks *et al* have found that the following field conditions affect scald:—

(a) Mature fruits scald less than immature.

(b) Apples from trees heavily irrigated scald more than those lightly irrigated,

and have found that if aeration of the store is properly carried out, scald does not appear. They suggest that to attain this, the following conditions should be observed:—

(1) Storage packages (i.e., cases) must be well ventilated.

(2) At 0°C. (32°F.) scald does not become evident, but appears between this and 20°C. (68°F); although not evident at the time, it shows up when the fruit is removed to a warmer atmosphere.

(3) Stacks and aisles should be arranged in such a manner that air currents may pass readily down the aisles, and between cases in each stack.

(4) Cases exposed to a continuous air current of 0.66 miles per hour in cool-store are found to remain free from scald.

(5) Stirring of the air (including constant air currents) is more important than air renewal in the prevention of scald.

(6) Wrapping of fruits in paper impregnated with certain oils and fats has reduced scald to a negligible quantity.

From these facts it becomes apparent that scald is due to production by the fruit of harmful esters, which, at the low temperature in cool-store, do not volatilise quickly enough to avoid injury to the fruit unless constantly removed by sufficient aeration. The experiments of these authors show that the question of control resolves itself into the simple matter of proper aeration, for if the cases are stacked in such a manner as to allow a current of air to pass between them, and the air kept moving at a rate of not less than 0.66 miles per hour, then scald will give little or no trouble.

SUMMARY.

1. Scald is a physiological disease confined to the fruit of the apple. It is essentially a cool-store trouble.

2. Scald is due to the accumulation of esters or similar gases of the apple in the tissues of the affected regions.

3. Mature fruit scalds less than immature; heavy irrigation tends to increase it.

4. Control consists in the thorough aeration of the cool-store.

For literature references regarding this disease, see bibliography, p. 349, numbers *57, 58, 59.*

BITTER-PIT.

Syn.: Confluent bitter-pit; crinkle; stippen.

This disease is apparently known wherever the apple is grown, being world-wide in its distribution. In New Zealand it is not uncommon on the pear, and has been found in addition on the quince, though this latter host is rarely affected. It is prevalent throughout, occurring equally on apples grown on the rich silts of Hawke's Bay and Central Otago, the pumice soils of the Auckland province, and the heavy clay soils of Nelson. The disease was first recorded for New Zealand by Kirk *(182)* in 1898.

APPEARANCE AND EFFECT ON THE HOSTS.

This trouble is confined to the fruit, and may appear when the fruit is nearing maturity whilst on the tree, or when mature and in store or cool-store. On the tree, it may appear in every fruit, or only those on one branch may be affected, or, as sometimes happens, only one or two fruits on a branch may show signs of the disease, so erratic may be its appearance.

The disease appears first in the form of small dark-coloured spots usually sunken slightly below the surface, scattered over it.

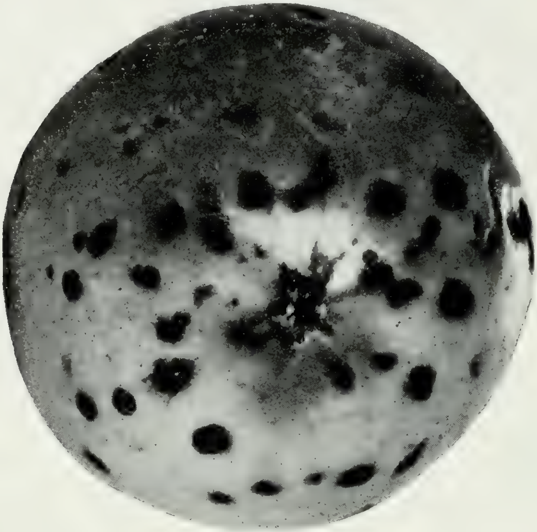


Fig. 87. BITTER-PIT ON APPLE FRUIT. Natural size.

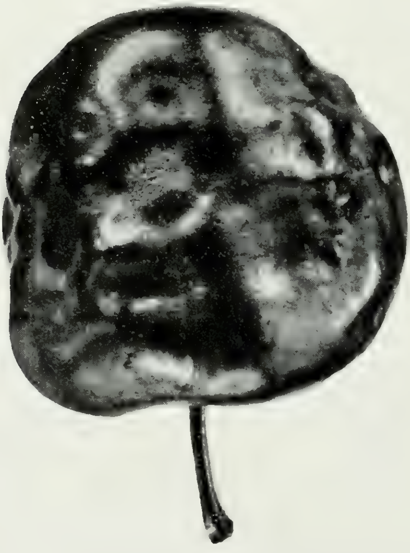


Fig. 88. BITTER-PIT ON APPLE FRUIT; CONFLUENT CONDITION. Nat. size.

Photos, E. Bruce Levy.

but usually more numerous near the blossom end of the fruit (Fig. 87). These spots may range in size from 2 mm. to 6 mm. or more across, and at first are usually circular in outline. Later the spots may increase in size, or, by the interpolation of other spots between ones already in position, may form an area extending over the greater part of the fruit (Fig. 88). A section through a fruit infected with bitter-pit, shows the spots to be scattered throughout the flesh (Fig. 90), many more being present than can be seen on the surface. Sections show each spot to consist of brown tissue, tougher in texture than the normal flesh, and more spongy in appearance. When tested with reagents the cells are found to be quite dead, and are seen to be filled with starch grains.

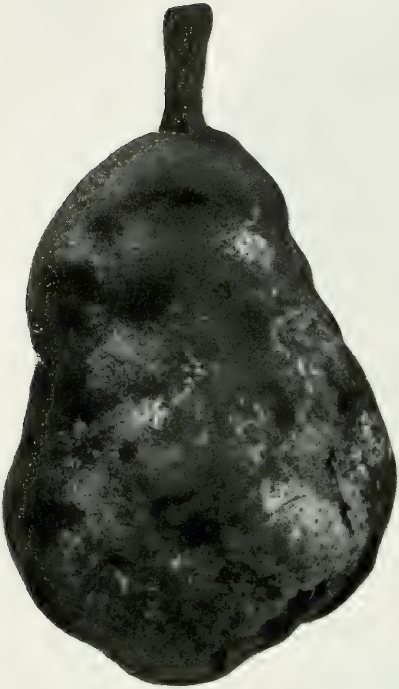
ECONOMIC IMPORTANCE.

The disease affects the fruits, forming the discoloured spots discussed above. It does not cause a rot, for fruits affected with bitter-pit keep as well as the normal fruits. But the spots give to the fruit an unsightly appearance, and as they are somewhat bitter to the taste, they affect the dessert quality of the fruit, and thus lower their market value. As frequently 30% or more of the crop in certain seasons may be affected, it follows that the depreciation in value may have a depressing effect upon the markets. Particularly would this be the case with export fruit, for if when opened up in the markets cases were found to contain a high percentage of fruits affected with bitter-pit, it follows that the prices offered would be low.

CAUSE.

Numerous theories from time to time have been brought forward as to the cause of this disease; that it was caused by fungi or bacteria; insufficient soil water; premature and imperfect ripening; result of fruits being subjected to too high a temperature at the period of ripening, with a result that the cells were killed by fermentation; starvation of groups of cells; arsenical injury; insect injury; concentration of sap, with a resultant concentration of acids, resulting in the death of the cells; but all have failed to stand the test of direct experiment.

No definite cause is yet known, but it is probable that the two most recent theories given below arrive closely as to the cause or causes of bitter-pit. From a reference to p. 24 it will be seen that the whole flesh of the apple is permeated with the conduction vessels, the smaller branches of which are more numerous near the periphery of the fruit. In the cells of unripe fruit large quantities of reserve food is stored in the form of starch. As the fruit ripens this starch is converted into sugar. The dead cells in the affected



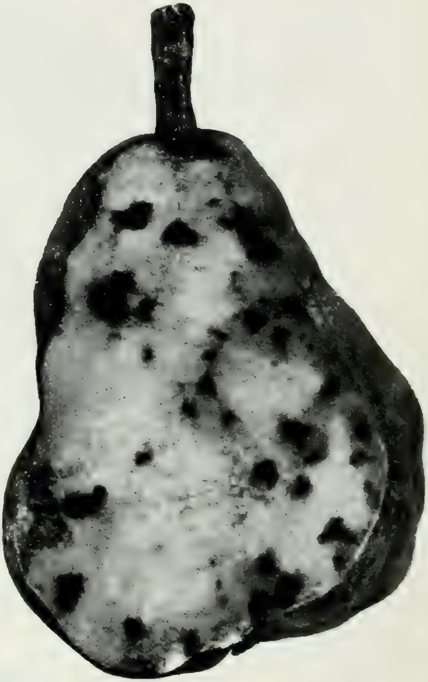


Fig. 89. BITTER-PIT ON PEAR FRUIT. Natural size.

Fig. 90. BITTER-PIT ON PEAR FRUIT. Natural size.
The fruit has been sectioned to show the pits scattered throughout the pulp cells.
Photos, E. Bruce Levy.

regions are found to contain large quantities of starch, thus tending to show that the injury has occurred *before* the fruit has reached maturity. Now these affected areas occur in or near one or more of the small conduction vessels, as has been demonstrated by McAlpine *(215)*.

McAlpine's theory to account for the cause of bitter-pit, has recently been summarised by that author *(220)*. This, which may be termed the Bursting Cell Theory, is as follows:—

> "From the point of view of bitter-pit, the most important structure in the apple or pear is the continuous vascular network immediately beneath the skin, where bitter-pit originates. This network . . . forms the boundary between the pulp and the skin, and has the important function of regulating the supply and distribution of the sap, to nourish the increasing pulp cells and the expanding skin in the growing apple or pear. We can now understand why this regulating system of vessels exists, and how, if it is interfered with in any way, a derangement of the

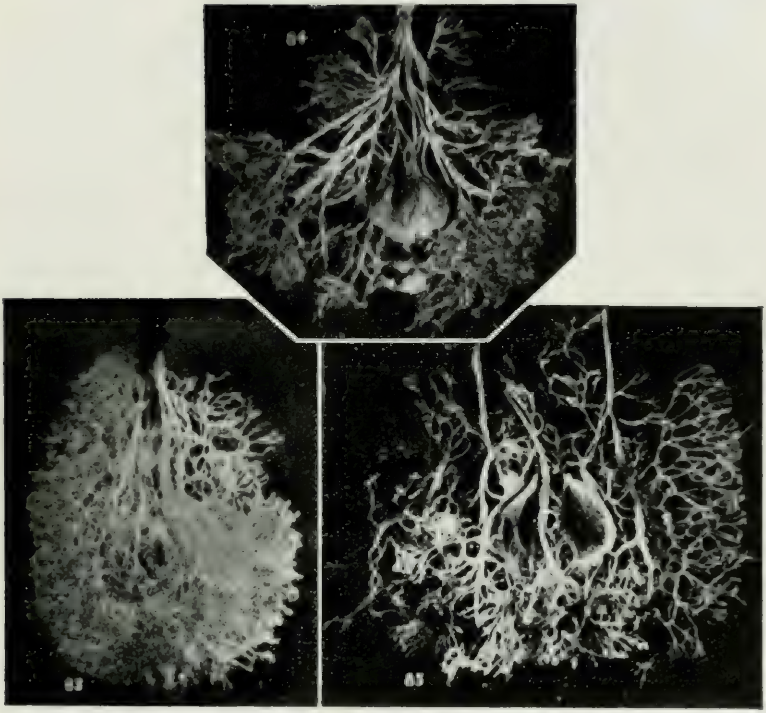


Fig. 91. VASCULAR SYSTEM OF THE PEAR FRUIT.
After McAlpine (215).

tissues takes place. Wherever bitter-pit occurs this vascular network is ruptured and the pulp cells there have become brown and dry, resulting in the consequent . . . depressions in the skin, which constitute the external symptoms of the disease. We can now picture to ourselves how bitter-pit originates.

"When there is an extra rush of sap, following on dry conditions, the rapidly swelling pulp cells at the external boundary burst the vascular network at localised spots, and the sap pressure which is sufficient to rupture the enveloping network, also bursts the thin-walled pulp cells at these particular spots, and death of the cells ensues. Briefly, it may be stated that rapid alternations between dry and moist conditions, combined with fluctuating temperatures, during the growing stages of the fruit, is the exciting cause of bitter-pit. Hence, the inherent difficulty of the task of preventing bitter-pit in the orchard in a locality subject to such fluctuating conditions of humidity and temperature."

This is one explanation as to the probable killing of the cells; the subsequent browning he believes *(215)* to be due to an oxidising enzyme which, in the presence of tannin, causes the group of burst cells to become brown.

An alternative theory, the Crushed Cell Theory, has recently been proposed by Herbert *(159)*. This, briefly, is to the effect that the affected cells have been killed by being crushed by neighbouring cells having a higher osmotic pressure due to their higher proportion of sugar. He claims that the following facts support his view:—

(*a*) The presence of starch in the bitter-pit cells.

As pitting occurs in the apple for the most part at a time when the starch is being converted into sugar, when there is a rush of sap into the fruit, the cells in which the starch has been converted into sugar will swell to a greater extent and more rapidly than those which still have starch in the cells. This rapid distension of the cells is resisted on the outside of the skin, so that as the cells expand they crush these cells in which starch transformation is backward, thus accounting for the presence of starch in quantity in the dead cells.

(*b*) Intact skin over the pitted areas, and the first external symptoms being a sinking of the skin.

If bursting of the cells were to occur, distension would precede bursting, with the result that the cells would take the line of least resistance, and production of wart-like bodies on the surface of the fruit would result; instead of which the appearance of sunken tissue is the first symptom of the disease.

(*c*) A vascular bundle may run through a pit area and supply healthy tissue beyond.

This would not be the case if the net-work was ruptured.

(*d*) Tensile strength of cellulose sufficient to eliminate the possibility of bursting.

Herbert accepts the theory that fluctuation of the water supply is the primary factor responsible, but questions the theory regarding the manner in which the pits are produced.

REMEDIAL TREATMENT.

McAlpine's researches into the cause and treatment of this disease extended over a period of five years, during which he tested every theory, practicable or otherwise, as to the cause and control of bitter-pit, with the result that he came to the conclusion given above as to the *cause,* but failed to arrive at the precise field condition or conditions responsible for the fluctuating sap-pressures. He believed that the root of the trouble lay in the fact that the modern apple was of a highly artificial nature, for it had been derived by selection from the wild crab, and to gain succulence, toughness of the structure necessarily was sacrificed, the penalty being a weakened constitution.

He arrived at the conclusion that control measures lay in an appreciation of the following factors:—

(1) That experiments with different stocks may have a beneficial effect on the problem;

(2) That the solution of the problem lay in the breeding of immune varieties by selection and crossing.

This would require many years of experimental work, and finally—if success were obtained—would probably result in the replacement of modern varieties with the strains so produced.

Meanwhile he has suggested that the following precautions be adopted, for his experiments gave results which justify these being put into operation:—

(a) Prune lightly, for light pruning is associated with a small amount of pit, severe pruning with a large amount.

(b) Where irrigation is practised (as in Central Otago), the water should be sparingly used, for heavy watering induces bitter-pit.

(c) The age of the trees has an influence on the development of bitter-pit, young trees being much more susceptible to the disease than old and heavy-bearing trees.

(d) For export purposes, pick fruit when it has reached full size, but before it is fully ripe.

SUMMARY.

1. Bitter-pit is a non-pathogenic disease affecting the fruit of the apple, pear and quince.

2. It is probably caused by over-pressure of water in the constitutionally weakened tissues of the cultivated apple.

3. It may be reduced by *(a)* light pruning; *(b)* sparing use of irrigation water; and may be held in check in cool-store and transit, by picking the fruit before it becomes fully ripe.

4. As trees become older they tend to become less susceptible.

For literature references regarding this disease, see bibliography, p. 349. Nos. *136, 159, 182, 215, 216, 217, 218, 219, 220.*

FLESH-COLLAPSE.

This is a cool-store trouble which suddenly made its appearance in 1920 *(321)*. It is confined to the apple, and appears to be common on the varieties Ballarat Seedling, Cleopatra, Dunn's Favorite, Jonathan, Rome Beauty, Stark, Sturmer and Winter Pearmain, less so on Delicious, Docherty, and London Pippin.

A certain amount of confusion exists in the literature dealing with this disease, but it would appear that "internal browning," or "internal break-down," is similar to, if not identical with, flesh-collapse, whereas "brown heart" differs in that it appears only in fruit carried in cool-chambers on board ship. No data are available as to the prevalence of the trouble elsewhere, on account of this diversity of nomenclature.

APPEARANCE AND EFFECT ON THE HOST.

This trouble is essentially a cool-store one, for it has not been observed on fruits in the orchard or in ordinary store. It appears in the pulp of the apple, and has on occasions been observed in or near the core. When the disease is slight, a light brown colour, tinged with pink, may be seen in transverse section forming a more or less narrow band running parallel with and close to the skin or a portion thereof. The pulp cells in the affected zone are seen to be somewhat moister than the normal and are soft to the touch. At this stage the disease is not apparent on the exterior, the skin appearing quite normal. In cases where the disease is more severe the band of discoloured tissue is wider, darker in colour, and more watery, and the whole apple feels soft to the touch, although no indication of the presence of the disease is apparent on the exterior (Fig. 92). In extreme cases the entire pulp is brown throughout, very soft and watery, and the skin may appear slightly discoloured. In addition, some varieties show a discolouration of the vascular system.

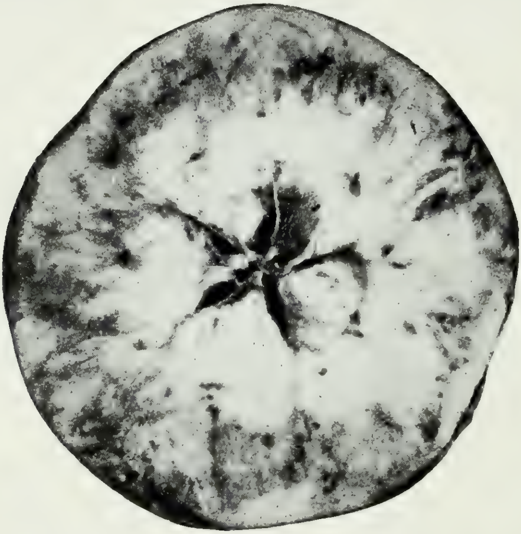


Fig. 92. FLESH-COLLAPSE OF THE APPLE. × $\frac{2}{3}$.
Typical condition after the fruit has been exposed to the air at normal temperature.
Photo, W. D. Reid.

Microscopic examination shows that affected pulp cells first lose their turgidity, and finally collapse, hence the name of flesh-collapse as applied to this condition by Waters *(321)*. No pathogen is present in affected tissues.

The trouble apparently does not appear until the fruit has been in cool-store for some considerable time; for example, in 1923 it was found that the disease did not develop in 7 weeks; after 10 weeks 2% of the apples examined were found to be affected; in 15 weeks 22%; and in 25 weeks 39%.

ECONOMIC IMPORTANCE.

That this is a serious trouble is evidenced by the following figures, which, taken in conjunction with the figures (p. 177) of losses due to soft-rots show that cool-store losses are a serious factor in reducing profits. Waters has estimated that in 1922 over 100,000 bushels of apples were lost through this trouble. He found that in certain lines, as high as 80% or, in some cases, 90% of fruit were affected with flesh-collapse; whilst 20-30% were not infrequently affected.

The effects of such a disease reach beyond the cool-store, for owing to the fact that mild cases of affection are not apparent to the eye, many affected fruits are packed and despatched to the markets. As it is one of the peculiarities of this disease that it tends to become worse when slightly affected fruits are exposed to normal temperatures, such fruits invariably open up in a damaged condition. Then, too, when retailers have suffered losses through handling such fruit they are disinclined to buy largely and will only pay small prices for the fruits they do buy.

CAUSE.

The cause of this trouble is as yet unknown, for investigations into the nature of the disease are still under way.

The 1920 experiments conducted by Waters *(321)* showed that:—

(*a*) Flesh-collapse was a cool-store trouble;

(*b*) Certain field conditions were contributory factors;

(*c*) It was induced *abundantly* by reason of certain physical storage conditions; and

(*d*) Improved conditions of ventilation and humidity would make for better storage.

In 1921 *(323)* he concluded as a result of further researches, that:—

(*a*) There appeared to be some relation between long working hours (of the refrigerating plant), low average temperatures, and abundant flesh-collapse, and shorter working hours, higher average temperatures and less flesh-collapse; and

(*b*) The quality of the flesh of certain varieties, lines, or individual fruits when they reach cool-store is such as to render them more liable to flesh-collapse.

In 1922 *(324)* a continuation of his experiments led Waters to the following conclusions:—

(*a*) Over-maturity of the fruits contributes largely to the prevalence of flesh-collapse in unfavourable storage.

(*b*) Certain changes in the running of the plant would enable the ventilation and humidity of the chambers to be better controlled, leading to a quicker passage of gaseous and vapourous apple bye-products from the apples to the air outlets of the chambers.

In 1923 numerous experiments demonstrated that faulty aeration was not a major factor.

In 1924 Waters (*324b*) was led to study the temperature-humidity ratio, for he believed that long running hours, a low flesh-temperature range, high relative humidity, and unwilted apples seemed to be associated with flesh-collapse in cool-store, whereas shorter hours, higher temperatures, lower humidity, and consequent wilted condition appeared to result in greater freedom from the disease. His experiments led him to study loss in weight of stored apples (due to loss of water, etc.) with a view to determining whether this would be a useful measure in ascertaining the effects of different temperature-humidity ratios. In a later paper (*324c*) he gives particulars of the season's loss in weight experiments, and in addition the effect of maturity of fruit at time of picking, under these conditions.

In his loss in weight experiments he uses the *fruit* as indicators of progressive effects of cool-storage, basing his observations on loss in weight as the *factor* upon which circulation, temperature, or humidity should from time to time be increased or diminished. At the time of writing detailed results of his season's experiments are not available, but results obtained so far show that in his experimental chambers flesh-collapse has been reduced to 1.5 per cent. as against 50 per cent. for a corresponding period (November) the previous season.

A summation of the investigation to date leads to the following conclusions:—

(1) Over-maturity is a contributory factor under unfavourable storage conditions.

(2) The seat of the trouble lies in the physical condition of the cool-store.

(3) Ventilation is not a major factor.

(4) The main factor has not yet been located.

Control measures cannot as yet be indicated, but from the fact that over-maturity is a factor in inducing flesh-collapse, growers may expect to reduce their losses from this trouble by at least 25 per cent. by paying especial attention to picking their fruit when it has become mature, but before it has become over-ripe.

For literature references regarding this disease, see bibliography, p. 349, Nos. *30, 321, 323, 324, 324b, 324c.*

FROST-INJURY.

Occasionally fruits in New Zealand are damaged by frost; or as has occurred in certain localities, practically all the fruit just after it has set is cut by frost and falls to the ground.

A peculiar instance of frost-injury was brought to the author's notice recently, where in Otago a late frost had frozen the drops of water which had collected around the calyx of the immature fruits. This led to the killing of the epidermal cells in this region, consequently when these fruits reached maturity they all bore a russeted zone around the calyx (Fig. 93). Had one not been informed as to the nature of this injury, it would have been impossible to assign a cause.

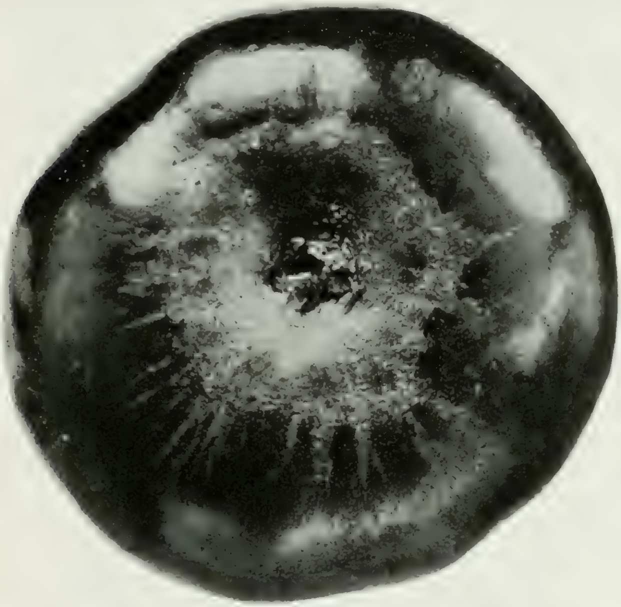


Fig. 93. FROST-INJURY. Natural size.
An unusual condition due to the freezing of drops of water held by the calyx.
Photo by Author.

In those localities where the fruit is cut from the trees season after season by late frosts it would be advisable either to abandon the areas altogether, or else go in for orchard heating, a costly process where fuel is difficult to obtain.

In North America it has been estimated that the cost for orchard heating runs from £2 to £2 10s. 0d. per acre *(162)*, but it would cost considerably more in those localities in New Zealand where frost is at all likely to prove troublesome, owing to the proportionately higher cost of suitable fuel.

GLASSY-CORE.

Syn.: Glassiness; water-core.

This disease appears to have a world-wide distribution, for apparently it occurs wherever the apple is grown. It is confined to the fruit of the apple, and is apparently a varietal and seasonal trouble, for on certain varieties in certain seasons it is difficult to obtain a single apple free from this disease.

APPEARANCE AND EFFECT ON THE HOST.

The disease may appear on the exterior of the fruits, being visible as irregular translucent areas on one side of the fruit. These areas are not confined to any particular part of the fruit, for they appear to be equally common on either coloured or green side, calyx or stem end. They may be so small as scarcely to be noticeable, or may cover the major part of one side of the fruit. In other cases the disease is not visible on the exterior of the fruit, and is apparent only when the fruit is cut into, when an irregular glassy zone will be found usually surrounding the core (Fig. 94). The disease first becomes noticeable as small watery areas (forming watery lines of indefinite length) surrounding certain of the larger vascular bundles. These areas may enlarge and coalesce until a large portion of the fruit is affected.

Affected parts are noticeably watery (Fig. 95), insipid, and slightly sweetish to the taste, but this taste is not at all unpleasant for frequently the fruits are eaten without remark by the consumer. According to McAlpine *(215)*, analysis of such parts shows that they contain an excess of water, and a corresponding deficiency in acids and ash-constituents.

ECONOMIC IMPORTANCE.

Unless the disease is noticeable on the exterior it is scarcely likely that its presence would affect market prices to any extent, for, as previously remarked, affected fruits usually are eaten without comment. Furthermore, when fruits are held in store under favourable conditions, the trouble practically disappears, so that it would not materially affect the prices of stored fruit. It possibly may have a detrimental effect on fruits in that it would render them more prone to attack from storage rots, but this condition would be likely to arise only when the disease was present in an exaggerated form. In short, it is improbable that this disease does more than slightly reduce the market value of those fruits that are placed on the market without an intervening period in store.

For explanation of terms, see glossary, p. xi.

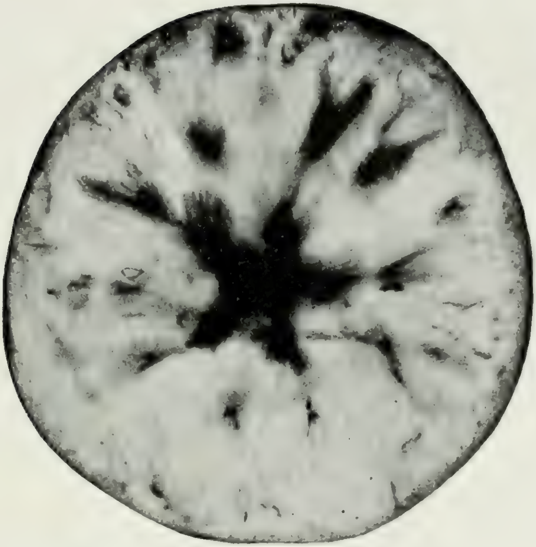


Fig. 94. GLASSY-CORE. Natural size.
Incipient stage, showing proximity of the trouble to the core and vascular bundles.
Photo, H. Drake.

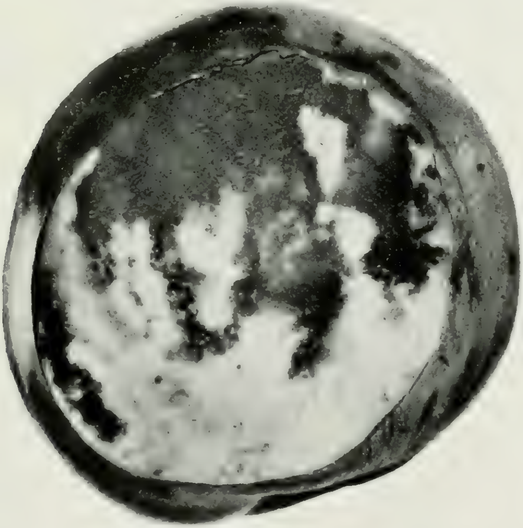


Fig. 95. GLASSY-CORE. Natural size.
The fruit has been sectioned so that the extent of the trouble may be seen.
Photo, E. Bruce Levy.

CAUSE.

Glassy-core is due to the intercellular spaces between the pulp cells becoming filled with water, which replaces the air normally present therein. This lends to the affected tissues a transparent appearance, with the result that they become translucent and present the glassy appearance so characteristic of this trouble.

The factors inducing this condition are not so well understood, however. Unequal conditions of temperature and humidity may affect transpiration; or a lowering of the rate of transpiration may result in a greater sap-pressure, with the result that water finds its way into the intercellular spaces, driving out the air and giving rise to glassy-core.

No definite evidence is forthcoming as to the conditions governing the production of this disease, but in certain susceptible varieties the following factors have been found to contribute towards its production:—

(a) Excessive growth;

(b) Excessive water supply, whether due to excessive rainfall or faulty irrigation;

(c) Excessive pruning, resulting in excessive growth;

(d) Partial defoliation during the growing season;

(e) Too dense a shelter belt surrounding the orchard.

In short, all factors tending to decrease transpiration and affect sap-pressure, are liable to induce glassy-core.

REMEDIAL TREATMENT.

Owing to the fact that many conditions over which the orchardist has little or no control may influence the prevalence of this disease, little can be done in the way of suggesting remedial treatment. Fortunately it is a trouble that invariably vanishes when infected fruits are held for a few weeks in store. So that fruit known to be affected should be held in store for a few weeks, under which conditions the trouble will disappear. If such fruit is to be placed in cool-store, then it is advisable first to hold it in ordinary store for about three weeks; for it disappears extremely slowly in cool-store. What happens in ordinary store is this: through lenticels scattered over the surface of the fruit (which are in communication with the intercellular spaces) the excess water slowly passes in the form of water vapour. This gradual loss of excess water goes on continuously, save when the surrounding atmosphere is at saturation point.

In cool-store, the temperature is low, and the water passes away much more slowly in consequence, partly because the humidity of a cool-store is generally high, partly because the water-vapour tension is low.

SUMMARY.

1. Glassy-core affects the fruit of the apple, forming in the tissues irregular translucent areas.

2. These areas are due to the presence of excess water in the intercellular spaces between the pulp cells, which normally are filled with air.

3. Lowered transpiration, with consequent increased sap-pressure, is the inciting factor.

4. The disease disappears when fruits are placed in ordinary storage for a few weeks.

For literature references regarding this disease, see bibliography, p. 349, Nos. *215, 229, 231.*

JONATHAN-SPOT.

Syn.: Cool-store spot; freckles; surface-pit.

The name by which this disease is known is rather a misnomer, for it commonly occurs on apple varieties other than the Jonathan. It is confined to the fruit of the apple, and has been recorded from North America and Australia (*219*), and is not uncommon in cool-stores in New Zealand.

APPEARANCE AND EFFECT ON THE HOST.

It may appear on the fruit whilst on the tree, or after it has been placed in cool-store, the latter being the prevalent condition in New Zealand. The disease appears in the form of small, circular, brown, slightly depressed spots, varying in diameter from 2 to 12 mm., scattered over the fruit, but usually more abundantly towards the calyx end. The spots, when first formed, are light brown and scarcely depressed below the surface, but later they become dark brown and more depressed, when they present an appearance not unlike bitter-pit, or even more closely resemble apple-spot. But they may be distinguished from these diseases in that they are scarcely more than skin deep, and do not at any time extend into the pulp cells.

The early stages of this trouble are confined to the colour bearing cells of the skin, and are usually found to be present in the vicinity of the lenticels. It occurs only on mature fruit, and in New Zealand develops only on fruit that has been held for some time in cool-store.

ECONOMIC IMPORTANCE.

As the spots are confined to the skin and are removed in peeling, they do not affect the quality of the apple, but merely its appearance. Where at all numerous they may slightly affect the market value, but as a rule spots of this nature are overlooked by the consumer, so that the economic importance may be considered as slight. The most serious aspect of this disease is that it renders the fruit liable to infection from one or more of the various storage rots.

CAUSE.

The cause of this disease is unknown; various theories have been propounded, as, for example, spray injury; gases from cooling plant; heavy irrigation; dry seasons; fungus attack; chilling of the fruit; insect punctures; but all have failed for lack of experimental evidence. The most plausible theory, recently propounded, is that the trouble is induced through faulty respiration of the fruit, resulting in the destruction of certain of the colour cells of the skin in the vicinity of the lenticels, through their coming in contact with certain gases produced by the apple.

REMEDIAL TREATMENT.

As in New Zealand the disease develops only after the fruit has been in store for some time, it would be advisable to place infected fruits on the market so soon as the disease becomes noticeable. In cool-store attention should be given to thorough aeration of the chambers in which susceptible varieties are stored.

For literature references regarding this disease, see bibliography, p. 349, Nos. *57, 61, 219, 275.*

MOULDY-CORE.

This trouble is prevalent in Australia *(215)* and New Zealand on certain varieties of apples, notably the variety Cleopatra. Apparently normal apples, when cut open, are frequently found to be decayed in the region of the core. The diseased area may appear brown and firm, or may be filled with a white (Fig. 96), blue or green mould. The decay may extend but a slight distance into the flesh, or the major part may be quite rotted, a condition common when the fruit has been stored for some time.

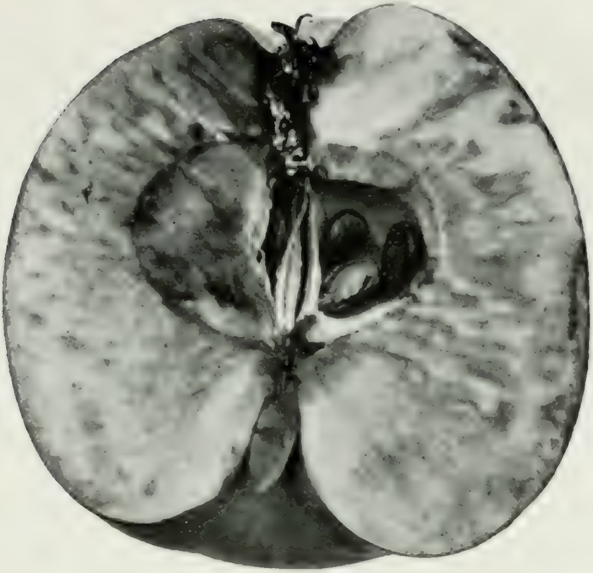


Fig 96*a*. INCIPIENT STAGE OF MOULDY-CORE. Natural size. Note the white mycelial growth in the calycine sinus.

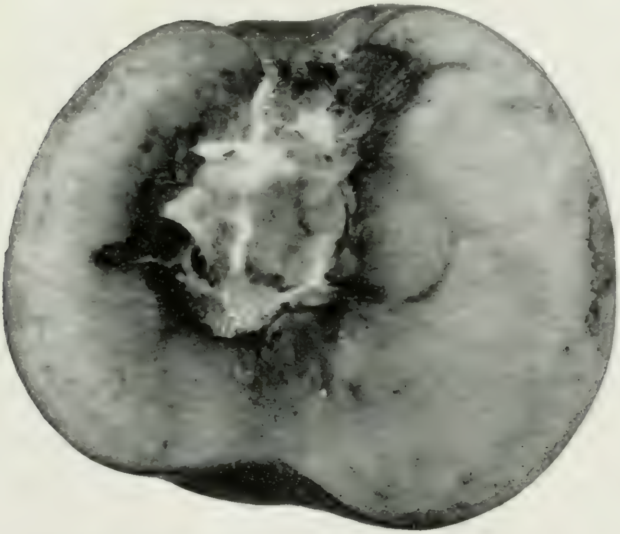


Fig. 96*b*. MOULDY-CORE IN DELICIOUS APPLE. × 6/7.

Photos, H. Drake.

CAUSE.

The primal cause of mouldy-core is due to defective variety, for infected varieties will be seen to possess a large open passage *(calycine sinus)* between the calyx and the core. If such an apple as Cox's Orange Pippin be cut open and examined, it will be seen that this passage is completely closed. When open it allows of the passage of wind- or water-borne spores of various fungi, which, should conditions be favourable, germinate and produce hyphae, which penetrate the tissues and set up this decay.

That this trouble is not due to any specific organism is evidenced by the fact that the author has isolated species of *Penicillium, Aspergillus, Rhizopus, Botrytis, Trichothecium roseum,* and has on occasion found bitter-rot, brown-rot, and black-rot in this cavity. Occasionally infected fruits are found in which the canal between the calyx and core is almost closed, and in such cases it is usual to find *Trichothecium roseum* present (see under pink-rot, p. 186). Most of these organisms in New Zealand are capable of effecting an entry to the fruit only through some injured surface, for the epidermis with its cuticular covering prevents entry. But this structure is absent in the centre of the fruit (which is usually much fissured internally), so it follows that infection may readily occur wherever the passage to the core is open.

REMEDIAL TREATMENT.

As the trouble is due to defective variety, it would be advisable when the disease is at all prevalent on certain trees to re-work them with a more suitable variety.

For literature references regarding this disease, see bibliography, p. 349, Nos. *215, 239.*

SOUR-SAP.

In New Zealand some 10 years ago a serious mortality of young fruit-trees occurred in the Nelson district, and to a lesser extent in several other localities. The trouble was not confined to any variety nor to any species, for both pome and stone fruits were affected. Although for several seasons this proved a serious trouble, to-day it is of minor importance.

The disease was first recorded for New Zealand by Cockayne *(93)* in 1915.

APPEARANCE AND EFFECT ON THE HOSTS.

On young fruit-trees the first indication of the presence of the disease appears in the spring, for when growth commences, and normal trees become clothed with leaves, affected trees are seen to remain in an apparently dormant condition. Or they may grow for a short time, and the leaves then wilt and turn brown. When the tissues of the branches and stem of such trees are cut into they are found to be brown and quite dead, and give off a somewhat sour or fermented odour, whence the name, sour-sap.

This dying of the branches appears to proceed from the tips downward, a condition usually evident when any root trouble is present(see under stag-head, p. 218).

On older trees the only characteristic symptom is the presence of the peculiar sour odour so noticeable when the cortex is cut into.

CAUSE.

Although at one time this trouble was believed to be due to fungous attack, it is now definitely known to be due to excess water in the soil, for the typical condition (accompanied by the sour smell of the browned cortex) has been found only where excess water has been known to occur.

Numerous fructifications of several fungi have been found on trees affected with sour-sap (e.g., conidial stages of *Valsa* spp., *Diplodia Griffoni* and *Fusarium lateritium*), but inoculation experiments have definitely shown that these are not the causal agents.

Fortunately, in those areas in which the disease was at one time prevalent, it was soon found that excess water was the cause, and draining operations applied, with the result that only on rare occasions does the disease now become noticeable.

CONTROL.

Control measures consist in the draining of affected areas.

Doubts have been expressed from time to time, by growers and others, as to the cause of this trouble being excess soil water. These doubts have arisen from the fact that many different diseases are liable to be confused with sour-sap.

For literature references regarding this disease, see bibliography, p. 349, Nos. *93, 317, 318.*

STAG-HEAD.

Frequently in neglected orchards trees are present the main limbs of which exhibit little or no growth, or may be dead at their extremities. This is a condition known as stag-head, a name borrowed from the forest pathologists, who apply it to trees which exhibit dead branches above a mass of healthy foliage. The name is derived from a fancied resemblance of these dead branches to the antlers of a stag. The trouble may occur on any type of fruit-, ornamental-, or forest-tree.

CAUSE.

Stag-head is due to lack of water, and consequently of food material. This may be induced by numerous causes, as under:—

(1) Root-fungus may partially destroy the root system;

(2) Through transplanting of large trees and consequent injury to the rooting system;

(3) Through trees growing in unfavourable positions, such as over a hard-pan;

(4) Alkali soils:

(5) Trees allowed to become overrun with grass and weeds;

(6) Starved soils.

In fact, any condition that would tend gradually to injure the root system so as to prevent the passage of the requisite quantities of water (with the necessary food substances in solution) would lead to this condition. The result is that the tree (or portion thereof) would commence to die gradually from the extremities downwards, until a point is reached when the roots and remainder of the tree are again in equilibrium. Thus, if a fairly large tree is transplanted in the winter, and the roots damaged as a result, it will be seen that growth will occur only from the lower parts of the tree, the extremities dying back for some distance.

A false stag-head condition may arise through the killing of branches, the extremities then appearing black and lifeless amongst the healthy foliage. Examination will show that this condition differs in that the dead branch will usually show some signs as to the cause of death; such a condition could be caused by fire-blight, valsa-injury, or some similar organism.

Remedial treatment would, of course, depend on a knowledge of the causes of the injury, and as these may be many, no general treatment can be suggested.

SUN-SCALD.

Occasionally on apples, rarely on pears, one finds fruits that have been damaged by action of the sun's rays. This trouble was the cause of a 50% loss to certain orchardists in Central Otago in 1924.

Affected fruits have a large elliptical, somewhat flattened area of discoloured tissue on the side facing the north. This area may be little more than skin deep, or may penetrate the flesh to a depth of 15 mm. or more, the tissues being dead and discoloured throughout this region. Affected parts are usually surrounded by bands of yellow and red colour, and rendered conspicuous on this account.

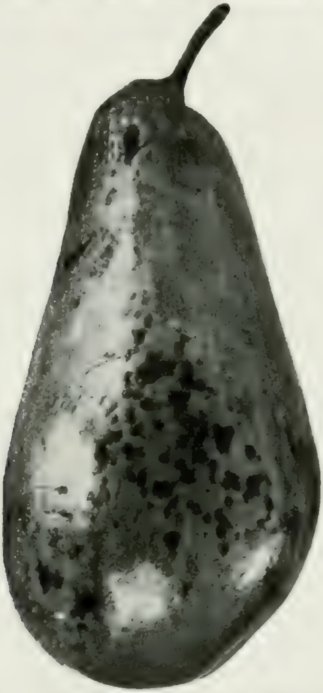


Fig. 97. SUN-SCALD ON PEAR FRUIT. × ⅔.

Photo, H. Drake.

No data are available as to the conditions favourable to the production of sun-scald, for one finds it to be present or absent on fruits on the same branch of the same tree, equally exposed to the sun.

But from observations made in the field the author is inclined to believe that it is more prevalent on unthrifty trees with a poor leaf development. Thus it should be possible to reduce the amount of sun-scald by inducing a healthy foliage.

CHAPTER XIX.

Table of Stone-Fruit Diseases; Artificial Key to Stone-Fruit Diseases.

The following table shows at a glance which diseases, in New Zealand, occur on the various hosts included under stone-fruits:—

Page.	HOSTS.					
	Almond.	Apricot.	Cherry.	Nectarine.	Peach.	Plum.
223	—	—	—	—	—	Bladder-plum
228	—	Brown-rot	Brown-rot	Brown-rot	Brown-rot	Brown-rot
242	—	—	Cherry-curl	—	—	—
245	Coral-spot	Coral-spot	Coral-spot	Coral-spot	Coral-spot	Coral-spot
252	Die-back	Die-back	Die-back	Die-back	Die-back	Die-back
312	Gummosis	Gummosis	Gummosis	Gummosis	Gummosis	Gummosis
257	Leaf-curl	Leaf-curl	—	Leaf-curl	Leaf-curl	—
264	Leaf-rust	Leaf-rust	Leaf-rust	Leaf-rust	Leaf-rust	Leaf-rust
272	—	—	—	Peach-scab	Peach-scab	—
278	—	—	Powdery-mildew	—	Powdery-mildew	Powdery-mildew
279	Root-fungus	Root-fungus	—	Root-fungus	Root-fungus	Root-fungus
304	Root-knot	Root-knot	Root-knot	Root-knot	Root-knot	Root-knot
279	Shot-hole	Shot-hole	Shot-hole	Shot-hole	Shot-hole	Shot-hole
284	Silver-leaf	Silver-leaf	Silver-leaf	Silver-leaf	Silver-leaf	Silver-leaf
294	—	Soft-rots	Soft-rots	Soft-rots	Soft-rots	Soft-rots
316	Sour-sap	Sour-sap	Sour-sap	Sour-sap	Sour-sap	Sour-sap
316	—	—	—	—	Split-stone	—
298	Valsa-injury	Valsa-injury	Valsa-injury	Valsa-injury	Valsa-injury	Valsa-injury

ARTIFICIAL KEY TO STONE-FRUIT DISEASES.

(Instructions regarding the use of the key
are to be found on p. 104).

A. BUD-DROP AND BLOSSOM WILT.

Canker present at base of bud or blossom.		
At base of bud	*Die-back*	(p. 252)
At base of blossom	*Brown-rot*	(p. 228)
Canker absent	*Frost injury*	

B. CANKERS ON LATERALS AND BRANCHES.

Gumming evident	*Brown-rot* *Coral-spot* *Die-back* *Valsa-injury*	(p. 228) (p. 245) (p. 252) (p. 298)

C. DISTORTED LEAVES.

Leaves curled and inflated	*Bladder-plum* *Cherry-curl* *Leaf-curl*	(p. 223) (p. 242) (p. 257)

D. FRUITS DECAYED, OR ROTTED.

Fructifications blue-green	*Blue-mould*	(p. 296)
Fructifications black	*Rhizopus-rot*	(p. 296)
Fructifications grey	*Botrytis-rot*	(p. 297)
Fructifications light brown	*Brown-rot*	(p. 228)

E. GENERAL DEBILITY OF THE HOST.

Leaves silvered	*Silver-leaf*	(p. 284)
Leaves yellowed.		
Roots more or less decayed	*Root-fungus*	(p. 279)
Roots apparently normal	*Soil trouble*	

F. GUMMING OF BRANCHES OR LATERALS.

Cankers present.		
Usually confined to laterals	*Brown-rot* *Die-back*	(p. 228) (p. 252)
Usually confined to branches	*Coral-spot* *Valsa-injury*	(p. 245) (p. 298)
Cankers absent	*Gummosis*	(p. 312)

G. LEAF DISCOLOURATION.

Leaves silvered	*Silver-leaf*	(p. 284)
Leaves yellowed.		
Roots more or less decayed	*Root-fungus*	(p. 279)
Roots apparently normal	*Soil trouble*	

H. LEAF PERFORATION, OR SHOT-HOLE.

Spots scattered, minute (2mm. or less)	*Die-back*	(p. 252)
Spots scattered, large (10mm. or more)		
Spots mostly circular	*Shot-hole*	(p. 279)
Spots irregular, frequently zoned	*Brown-rot*	(p. 228)

I. MALFORMATIONS OF FRUITS.

Immature plum fruits swollen and hollow	*Bladder-plum*	(p. 223)

J. MILDEW PRESENT ON LEAVES AND LATERALS

	Powdery-mildew	(p. 278)

K. SPOTS AND SCABS ON LEAF, FRUIT OR LATERAL.

(see also under leaf perforation).

On fruit.		
Spots circular, small.		
Spots black, superficial	*Peach-scab*	(p. 272)
Spots coloured, erumpent	*Die-back* *Shot-hole*	(p. 252) (p. 279)
Spots depressed, brown	*Leaf-rust*	(p. 264)
Spots irregular, large.		
Spots brightly coloured	*Leaf-curl*	(p. 257)
On leaves.		
Spots circular, minute (2mm. or less).		
Spots yellowish	*Leaf-rust*	(p. 264)
Spots purplish	*Peach-scab*	(p. 272)
Spots irregular, large (10mm. or more).		
Perforations numerous	*Shot-hole*	(p. 279)
Perforations present, not numerous.		
Spots zoned	*Brown-rot*	(p. 228)
Spots not zoned	*Die-back*	(p. 252)
On laterals.		
Spots superficial, regular, orbicular	*Peach-scab*	(p. 272)
Spots sunken, gumming evident	*Brown-rot* *Die-back*	(p. 228) (p. 252)
Spots erumpent, pulverulent	*Leaf-rust*	(p. 264)

L. TUMOURS PRESENT.

On roots or stem	*Root-knot*	(p. 304)

M. WILTING OF LEAVES.

On whole tree	*Sour-sap*	(p. 316)
On branches and laterals	*Coral-spot* *Valsa-injury*	(p. 245) (p. 298)
On laterals	*Die-back* *Brown-rot*	(p. 252) (p. 228)

CHAPTER XX.

STONE-FRUIT DISEASES.

(a) Fungous Diseases.

BLADDER-PLUM, Taphrina Pruni (Fcl.) Tulasne *(305)*.

Syn.: *Exoascus Pruni* Fcl.
Mock plums; plum-pockets; pocket-plums; starved plums.

Bladder-plum is world-wide in its distribution, occurring wherever the hosts are grown. In New Zealand it is confined to the plum, but in North America it has been recorded in addition on *Prunus virginiana,* and in North America and Europe on the bird-cherry, *Prunus Padus.* All varieties of cultivated plums appear liable to infection, but in New Zealand it appears, as a rule, only on the so-called Japanese plums, although English plums are occasionally infected. This disease was first recorded for New Zealand by Kirk *(180)* in 1896.

APPEARANCE AND EFFECT ON THE HOSTS.

Bladder-plum infects leaves, fruits, flowers, and shoots, but is most noticeable on the fruits about three weeks after blossoming; these become greatly enlarged, and after a time fall to the ground.

These enlarged fruits are at first somewhat globose, eventually becoming greatly elongated, and more or less curved and twisted (Fig. 98). They are spongy in texture, and when cut open are seen to be quite hollow, the stone and ovule not being developed (Fig. 101). They change in colour from green to white; at first somewhat smooth, they soon become much wrinkled. Finally they turn brown and die. Infected fruits on English plums present a slightly different appearance; they do not become larger than normal ones, but differ mainly in colour, being white, blotched with red (Fig. 99). They are quite soft and hollow, however.

The leaves become infected shortly after they unfold from the bud, when they appear blistered and yellow, or even red, resembling leaves of peaches infected with leaf-curl. They, too, after a time change to brown and fall to the ground.

For explanation of terms, see glossary, p. xi.

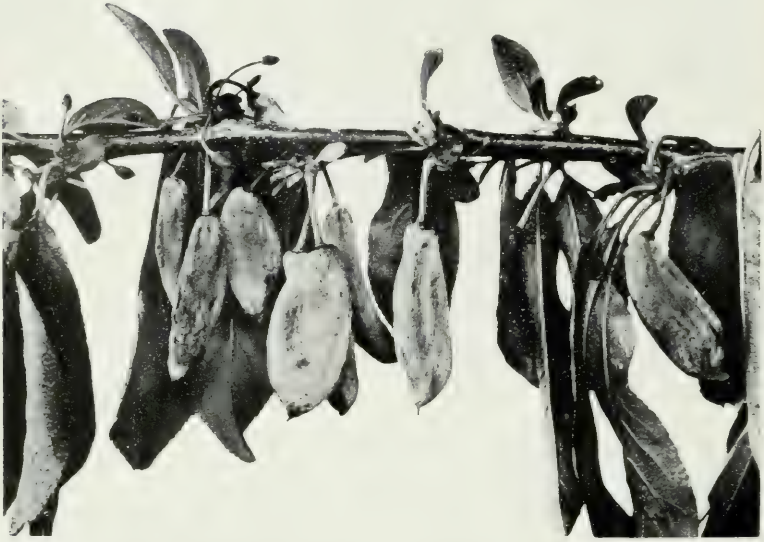


Fig. 98. BLADDER-PLUM ON JAPANESE PLUMS. × ½.

Photo, W. D. Reid.

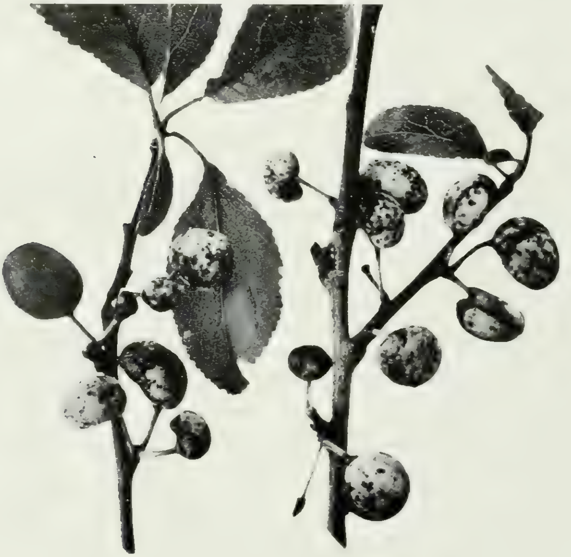


Fig. 99. BLADDER-PLUM ON ENGLISH PLUMS (Evans' Early). × ½.
Normal plum on the left; the dark spots on the infected fruits are red in nature.

Photo by Author.

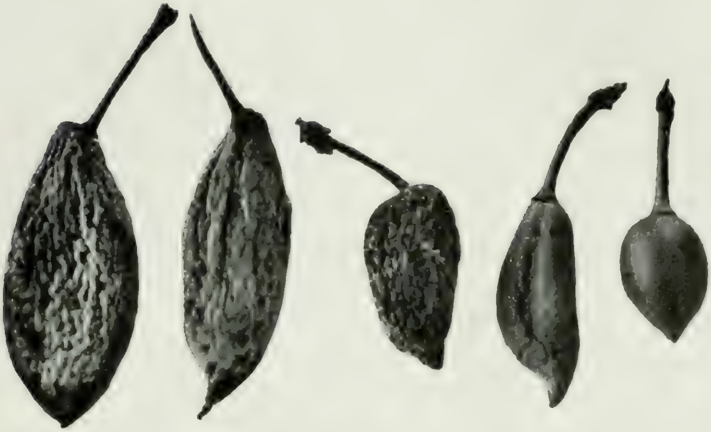


Fig. 100. BLADDER-PLUM ON JAPANESE PLUMS. Natural size.
Showing gradual development from the normal fruit (right) to severely infected fruits.

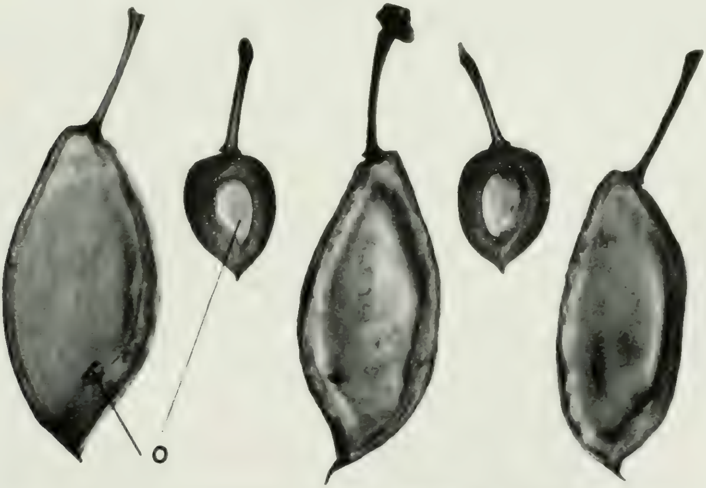


Fig. 101. BLADDER-PLUMS IN SECTION. Natural size.
Normal fruits between the infected specimens. Note the remains of the ovule *(o)*, and compare it with the normal ovule.

Photos. W. D. Reid.

o

Shoots are invariably attacked, when they appear lighter in colour and much swollen. They frequently become stunted, when the leaf-buds remain close together, and give a rosetted appearance to the branch; or they may be much twisted and killed for part of their length. Following the death of these laterals, small and weakly secondary laterals grow out immediately below the dead areas; these in turn become infected, and produce a further crop of diseased fruit the following season.

Blossoms are sometimes killed outright shortly after they emerge from the bud, but this is an uncommon manifestation, and doubtless occurs only when climatic conditions are favourable to the active development of the causal organism.

ECONOMIC IMPORTANCE.

As this disease is confined to plums, it may be claimed that its importance is slight, owing to the fact that plums do not figure among the more important commercial fruits. Nevertheless, to those growing these fruits its attacks may prove serious enough, for where infection is severe the greater part of the crop may be lost. As leaves, too, are attacked, partial defoliation and consequent debilitation of the tree may follow. Furthermore, shoots may be stunted, and in cases of severe infection killed outright.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Bladder-plum is caused by *Taphrina Pruni,* a fungus included in the same genus as that causing leaf-curl. In fact, the life-histories of both, so far as is known, are similar (see p. 260).

The hyphae of the fungus are perennial in infected shoots, and in the spring grow through the pedicels into the developing fruits, where they ramify through the mesocarp (fleshy part of the fruit) and stimulate this portion to excessive growth. Consequently, within a few days, infected fruits become doubled or trebled in size (Fig. 100). Growth of the stone and ovule is prevented; consequently, infected fruits are soft throughout and quite hollow (Fig. 101). Shortly after infection fructifications appear as a delicate bloom on the surface of these "bladder-plums." Doubtless leaves and developing shoots are infected in a similar manner, although infection may occur equally well from spores lodged in the bud-scales and bark-crevices. This would, in part, appear to be borne out by the fact that the effects of the disease can be somewhat reduced by one spray application; but that perennial mycelium plays a part in the perpetuation of the disease is obvious when one considers the fact that the latter cannot entirely be controlled by spraying as in the case of leaf-curl.

The mycelium continues to traverse the young shoots as they develop, so that once a branch has become infected the disease will persist in infected shoots until such time as they are removed.

For details of the life-history of the causal organism, see under leaf-curl, p. 260.

It is probable that extensive infection, especially fruit infection, is due to perennial mycelium situated in the shoots. This belief appears to be strengthened by the difficulty of control, for it must be admitted that more than 75% of clean fruit cannot be obtained by spraying alone.

CONTROL.

The following spray application is recommended:—

Spray Treatment for the Control of Bladder-plum.

Time of application.	Spray to Use.
When the buds begin to swell, but before they open.	5-4-50 Bordeaux, or 1-15 Lime-sulphur.

This application should be supplemented by the cutting out of infected shoots. This could be practised at any time during the growing season, as then the disease would be conspicuous, and consequently readily located. Paint over all wounded surfaces as soon as made with coal tar, using a stiff brush.

SUMMARY.

1. Bladder-plum is a fungous disease attacking leaves, shoots, blossoms, and fruits; causing leaves to become blistered, shoots to become distorted, buds to fall, and fruits to become swollen and quite hollow. It is confined to the plum.

2. The causal organism is *Taphrina Pruni.* This fungus overwinters by means of hibernating mycelium in the shoots, or by spores (ascospores or conidia) lodged in bud-scales and bark-crevices.

3. The disease is only partially controlled by spraying, so this treatment should be supplemented by cutting out of infected branches.

For literature references regarding this disease, see bibliography, p. 349, Nos. *119, 180, 305.*

BROWN-ROT, Sclerotinia cinerea Schroeter *(274)*.

Syn.: *Monilia cinerea* Bon.; *Sclerotinia laxa* Adherh. et Ruhld;
Sclerotinia americana Norton et Ezekiel *(230)*.
Blossom-blight; brown-rot canker; peach-rot; ripe-rot; twig-blight.

Brown-rot is the most serious of all fungous diseases occurring on stone-fruits. With the exception of Central Otago (excluding Roxburgh), where it is unknown, brown-rot is common throughout New Zealand, occurring on apricots, cherries, nectarines, peaches, and plums.

As a rule, it does not infect apples and pears, but occasionally it is found on these hosts. In such cases infection occurs through insect punctures or other skin-injury, the spores in all probability being carried to these injuries by insects or by wind.

Brown-rot is common in Australia, certain parts of North America, and on the Continent of Europe, where it is widely distributed. In Europe a brown-rot of pome-fruits is known, which is destructive to these hosts, but causes little or no damage to stone-fruits. In New Zealand this disease, caused by a related species of fungus, *Sclerotinia fructigena* Schroet., fortunately does not occur.

The conidial stage was first recorded for New Zealand by Kirk *(186)* in 1905; the ascigerous stage by the author *(115)* in 1922.

APPEARANCE AND EFFECT ON THE HOSTS.

As a rule, brown-rot appears first on the blossoms; but this stage, being governed in its occurrence by atmospheric conditions, may be absent, though a wet season following a cold winter is usually followed by blossom-infection, which may become so general that the greater part of the crop is lost. Infection may occur before the petals unfold, or shortly after they have opened, the period of infection extending from the beginning of September to the last week in October, according to the time of flowering of the variety. Following infection the blossoms die and turn brown, the mycelium of the fungus then growing through the pedicel and entering the shoots at the base of the bud, where it forms a small canker. During its formation gumming occurs, the gum exuding on to the surface of the shoots, where it tends to adhere to the dead blossom (Fig. 105) and hold it to the lateral, with the result that the dead blossoms do not fall but persist where they have been killed, often for several weeks. Blossom-infection may occur in another manner, through the mycelium of the fungus spreading from the young lateral up the pedicel to the blossom. In such a case it would appear that the lateral has first become infected, a small

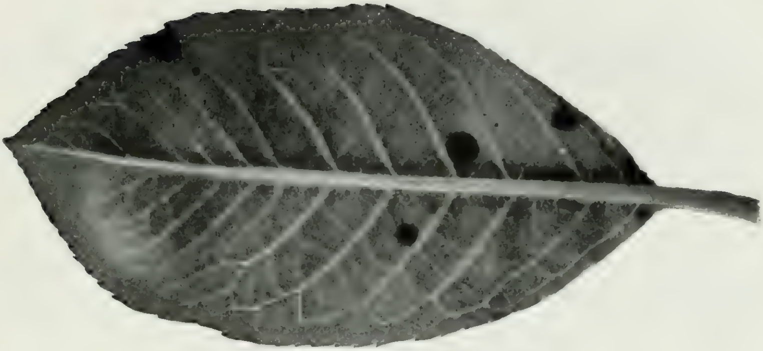


Fig. 102. BROWN-ROT ON PEACH LEAF. × 3.
Showing incipient infection.

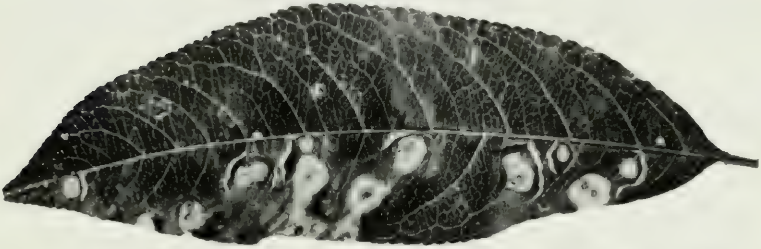


Fig. 103. LEAF-INFECTION; CIRCULAR DEAD AREAS HAVE BEEN KILLED BY BROWN-ROT. Natural size.

Photos, E. Bruce Levy.

canker being formed at the base of the bud, from which the mycelium has spread to the blossom as described above. Following the formation of cankers on laterals the mycelium of the fungus may continue to extend until the whole shoot becomes girdled, when it rapidly wilts and dies. This condition is commoner at the time of the maturing of the fruit, and will be discussed more fully below. As a rule, blossom-infection does not destroy all blossoms, but attacks a percentage only.

Infection of the developing fruits may directly follow blossom-infection, but generally the disease does not manifest itself until about the time of maturity of the fruits. Fruit-infection first becomes noticeable from the presence on the epidermis of small, brown, more or less circular areas. These spots are not clearly defined in the early stages from the healthy tissues, but as the rot progresses the outline becomes sharp, and about thirty hours after infection small, scattered, ashy-grey tufts of conidia appear upon the exterior of the infected areas. In from three to five days the fruit becomes discoloured and rotted throughout, the entire surface

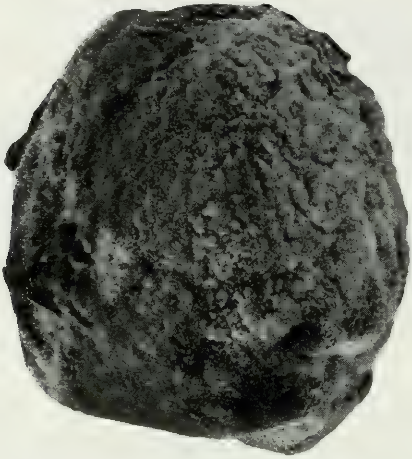


Fig. 104. FRUIT INFECTION. Natural size.
Mature peach fruit covered with the ashy-grey pustules of brown-rot conidia.

Photo, E. Bruce Levy.

being covered with the numerous conidial tufts, which may at first be scattered but soon become so closely packed together that the whole fruit appears as if covered with an ashy-grey powder (Fig. 104).

The fungus may continue to grow down the fruit-pedicel into the lateral at the base of the bud, and form small cankers similar to those already discussed, from which it may extend along the shoot until it comes to a large branch. It may penetrate this and continue to develop until it girdles the branch, which suddenly wilts and dies. On such a branch gumming is conspicuous, but the most noticeable effect is the wilting and browning of the leaves, which remain on the tree after their death. Quite a large portion of the wood of a tree may be killed in this way, the destruction of branches, of course, lessening the following season's output. Moreover, cankers may persist in these branches for several seasons, and thus become an important source of infection each year.

After a time infected fruits become somewhat hard in texture and wrinkled in appearance. The tissues being permeated with the mycelium, the fruit is now known as a "mummy." If the mummy persists on the tree until the following spring, the mycelium within is capable of producing conidia throughout the winter, and of acting as a source of infection the following season. In fact, the mummy is usually covered with these spores. Should the mummies fall to

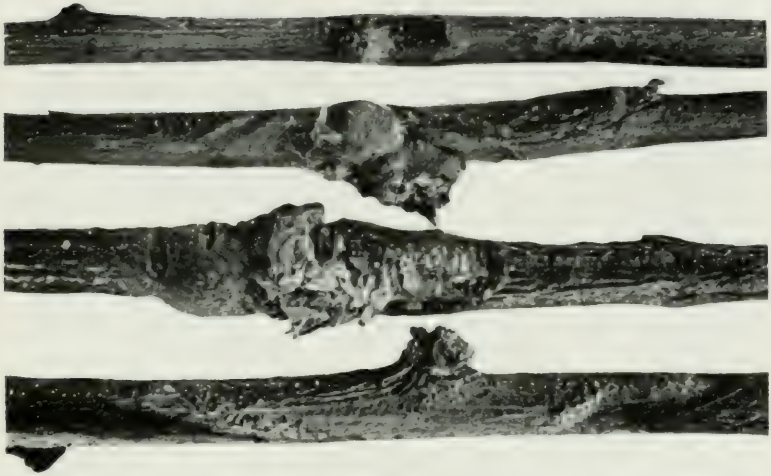


Fig. 105. BROWN-ROT ON PEACH LATERALS. Natural size.
The dead blossoms are attached by gum to the lateral; on the lowest a large canker has been formed, which has girdled completely the lateral. Pustules of conidia may be seen in this dead area.

Photo. H. Drake.

the ground the mycelium after a time undergoes a slight change, becoming darker in colour. In short, sclerotia are formed, from which, at blossoming-period, apothecia are produced.

ECONOMIC IMPORTANCE.

Until the year 1915 brown-rot was of comparatively little moment in New Zealand, but in the spring of that year great damage was caused both to blossoms and fruit. Since that date brown-rot has become the most destructive disease with which the grower of stone-fruits in this country has to contend. It attacks blossoms, shoots, leaves, and fruits, causing the death of blossoms, formation of cankers on the shoots, perforations in the leaves, and rotting of fruits. The effects of the disease are not limited to the orchard, as fruit commonly becomes infected during transit, and opens up on the market in a badly rotted condition.

Blossom infection causes a serious loss, as the infected blossoms are killed outright, and in cases of severe infection a tree may fail to set any fruit. The damage does not cease with the death of the blossoms, as the mycelium of the fungus frequently grows through the pedicel of the blossom into the shoot to which it is attached, and there forms small cankers, which may continue to enlarge until the shoot becomes girdled and dies, thus destroying tissue which should be available as fruiting-wood for the following season.

Leaf-infection is followed by the appearance of small, brown, more or less circular dead areas (Fig. 102), which later may fall away, leaving perforations in the leaf similar to those caused by shot-hole (Fig. 103). In extreme cases the leaves are killed outright, when they usually fall to the ground. When fruits become infected complete rotting follows within a few days, the entire crop being lost in cases of severe infection, as those familar with the disease have only too often observed.

Transit infection causes considerable loss, not only because a percentage of the fruit reaches the market in an unsaleable condition, but because in a season when brown-rot is prevalent the buyer is prepared to pay only a low price for fruit that may rot before being sold. Moreover, in order to safeguard himself against losses in the handling of infected fruit, he is forced to charge a correspondingly higher price for all sound fruit sold. Increased price has its effect on the market, as it limits the quantity of fruit sold to those few able to pay the high retail prices that are demanded.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Brown-rot is caused by *Sclerotinia cinerea,* a fungus having two spore stages (conidia and ascospores) in its cycle. For many years the fungus was known only from the conidial stage, which was named *Monilia cinerea.* In 1902 *(228),* however, Norton discovered the ascigerous stage growing from mummied plums in an American orchard. Until a few years ago this fungus was considered to be the same as that occurring on pome-fruits, but work on the part of Matheny *(210)* and Cooley *(104)* has shown that the organism on stone-fruits is quite distinct.

The disease may first appear at blossoming time, when the opening blossoms become infected. Infection may be due to (1) ascospores produced from mummies lying on the ground, (2) conidia produced from mummies hanging on the trees, or (3) conidia produced from mycelium overwintering in cankers on the laterals or branches. Whether infection is from ascospores or from conidia the method of attack is the same, for should the spores alight on the petals or other parts of the flower, and abundant moisture be present, each germinates and produces an infection hypha, which rapidly penetrates into and kills the tissues. Within a few days tufts of conidia may be produced on the petals, etc., of

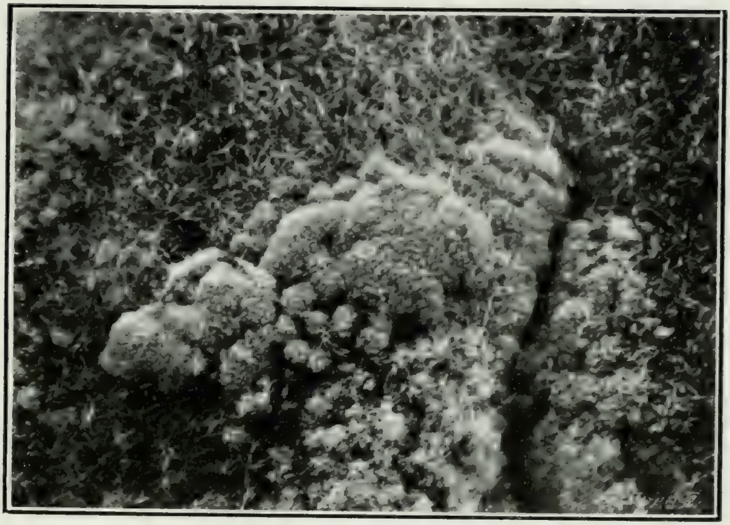


Fig. 106. CONIDIAL PUSTULES OF BROWN-ROT. × 10.

Photo, E. Bruce Levy.

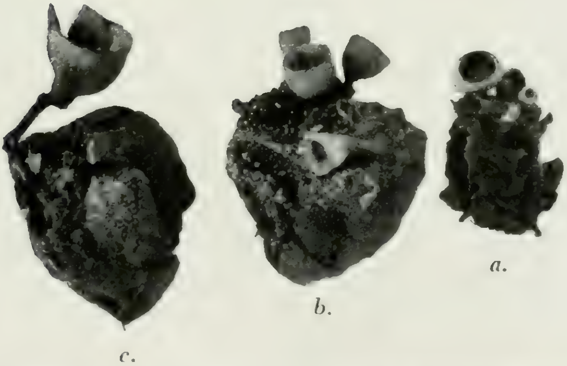


Fig. 107. APOTHECIA OF BROWN-ROT ON PLUM MUMMIES. Natural size. *a.* Urn-shaped immature specimens; *b, c,* cup-shaped mature specimens. The mummy in *c* was buried 5 cm. underground; note the long stalk of the apothecium.

Photo, W. D. Reid.

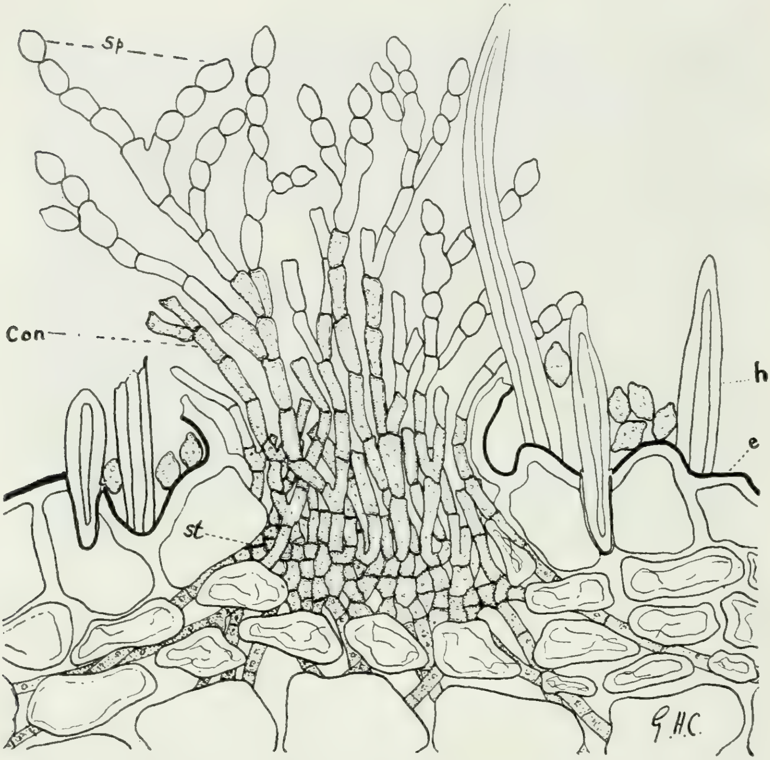


Fig. 108. SECTION THROUGH CONIDIAL PUSTULE ON PEACH FRUIT. × 375.

con. **Conidiophores;** *e.* **epidermis (cuticle indicated by heavy black line);** *h.* hair on epidermis; *sp.* conidia; *st.* stroma. Note conidia lodged on the surface between hairs of the fruit.

Original.

infected flowers, and they may also appear on the surface of the canker formed as the result of shoot-infection. Should they happen to be carried on to them, conidia may in turn infect developing fruits in their vicinity. In an ordinary season, however, the disease does not again become prevalent until the fruits near maturity, though in a wet one, fruit-infection may occur to a greater or less extent during the whole of the growing season.

As the fruits reach maturity the disease becomes noticeable, owing to the rapid manner in which they begin to rot. Infection at this stage may occur from conidia produced from mummies remaining on the tree, from conidia produced from cankers formed the previous season, or from conidia produced on blossoms and shoots as a result of blossom-infection. Ascospores, however, do not play a part in infection at this stage, as they are produced only at blossoming time. Whatever their origin, the conidia are carried on to the fruit by wind, insects, or even birds.

Although infection commonly takes place through wounds, it may occur wherever fruits are in contact (probably because moisture would be held at a point of contact for a longer period). In a wet season, however, infection may occur wherever the conidia happen to alight on the fruit. The conidia germinate in the presence of moisture and each produces an infection-hypha, which penetrates the epidermis and enters the tissues, beneath which it quickly grows and branches, producing a mycelium, the hyphae of which grow between the cells, killing them as they advance by the secretion of certain toxic substances. A closely woven mass of hyphae (stroma) is soon formed (Fig. 108, *st*), and from this is given off upright conidiophores (Fig. 108, *con*), which push through the now dead epidermis (Fig. 108, *e*), where they appear on the surface as small thread-like tufts. From the conidiophores conidia are produced. These are at first in chains (Fig. 108, *sp*), owing to the rapid method in which they are formed, but as they are only lightly attached to one another they soon become separated (Fig. 109 *b*), and appear as an ashy-grey powder upon the surface (Fig. 104). Conidia may be produced within thirty-six hours after infection, and in about four days the fruit may be completely rotted, so rapidly does the fungus develop. The hyphae from which the conidophores are produced continue to grow within the tissues of the fruit until the whole becomes permeated.

Infected fruits may remain on the tree until the following season, or they may fall to the ground. Should they remain, the mycelium may continue to produce conidia throughout the season. Conidia produced from these mummies during the winter months are slightly thicker-walled than those produced during the growing period, and are capable of remaining viable for several months (Fig. 109, *d*), thus differing from summer conidia, which remain viable for quite a short time—six weeks, or even less. It must not be overlooked that the hyphae of the fungus may grow through the pedicel into the lateral to which it is attached, and that it may continue down this until larger branches are reached; these may become girdled, and the whole branch in consequence be killed outright. This mycelium may persist for one or more seasons, and throughout the growing season give rise to conidia. This feature was very noticeable in 1915, and again in 1922, when laterals bearing mummies were commonly found to contain cankers.

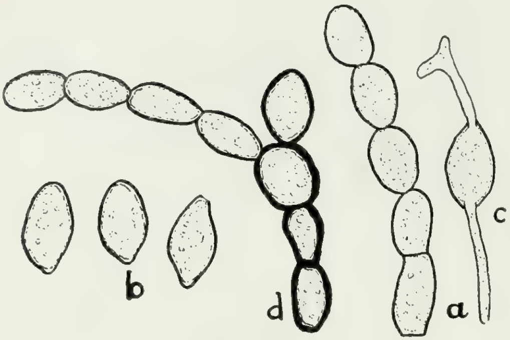


Fig. 109.

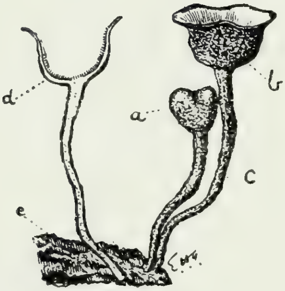


Fig. 110.

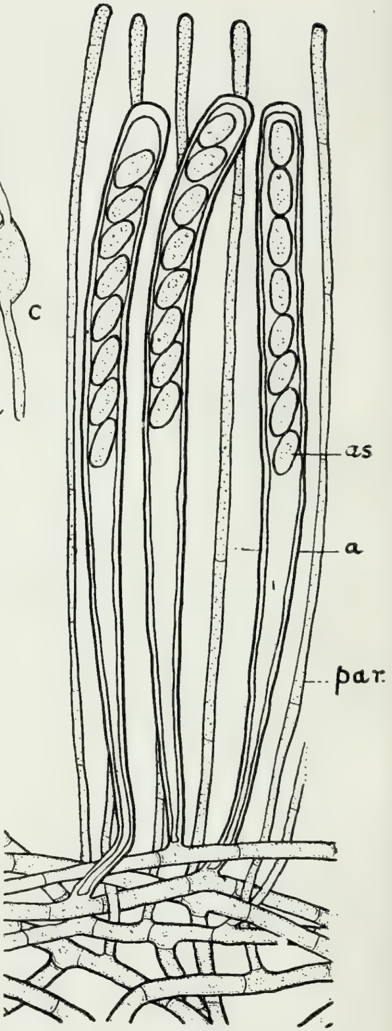


Fig. 111.

Fig. 109. CONIDIA. × 500.
a. Chain of thin-walled conidia; *b.* free conidia; *c.* germinating conidium, hypha protruding from each end; *d.* chain of thick-walled conidia. Generally on germinating these produce chains of thin-walled conidia.

Original.

Fig. 110. APOTHECIA. Natural size.
a. Immature; *b.* mature apothecium; *c.* stalk; *d.* section; *e.* portion of mummy.

Drawing by E. H. Atkinson.

Fig. 111. SECTION THROUGH HYMENIUM. × 500.
a. ascus; *as.* ascospores; *par.* paraphyses.

Original.

As to the formation of mummies, it will be remembered that following infection of maturing fruits the hyphae ramify through the tissues and finally completely permeate them. When these infected fruits fall to the ground the mycelium undergoes a slight change, becomes darker in colour and more compacted, forming sclerotia, which, according to Pollock *(242)* have been known to remain viable for as long a period as ten years.

At blossoming time the following season, should conditions prove favourable, these sclerotia give rise to apothecia. These vary in shape according to age and depth at which the mummies are buried. At first they are urn-shaped, with the margins turned inward, so that the hymenium is protected (Fig. 107, *a*), later becoming cup-shaped (Fig. 107 *b*), and finally, at maturity they are quite saucer-shaped, when the under-surface appears frequently to lie flat on the ground, the margins at this stage being much lacerated. In size they range from 2 mm. in diameter in the case of immature specimens to 18 mm. in mature ones. The saucer-shaped portion is concave on its upper surface, and the whole of this area is lined with asci (Fig. 111, *a*) and paraphyses (Fig. 111, *par*) arranged in columnar fashion, forming the hymenium or spore-bearing portion of the apothecium. The asci are long, cylindrical sacs (Fig. 111, *a*), each containing eight, colourless, one-celled ascospores (Fig. 111, *as*).

The length of the stalk of the apothecium varies according to the depth at which the mummies are buried in the soil, those lying on the surface producing apothecia with quite short stalks (10 mm. or less), while in the case of the deeply-buried ones—since the stalk must be of sufficient length to enable the apothecium to reach the surface—a length of 5 cm. or more may be obtained (in one specimen collected in New Zealand the stalk was actually 8 cm. in length). The apothecia are usually dingy brown when fresh, but change with age to dark brown. Should the mummy be lying on the surface, the apothecia are produced at the point of contact with the soil; in half-buried mummies they appear at the meridional line; while those formed on completely buried mummies appear to be produced from the portions nearest the soil-surface. When the mummies are more than one year old the sclerotia, as a rule, are all that remain, their presence becoming noticeable owing to the production of apothecia from them. They are usually irregular in shape, quite black, and are either attached to the stone or else isolated and partially buried, so that apothecia may appear in soil in which stones cannot be found.

If weather conditions are humid, the ascospores are ejected from the asci into the air (Fig. 111, *bis*), where they are caught and carried by air-currents to blossoms and young shoots in the vicinity.

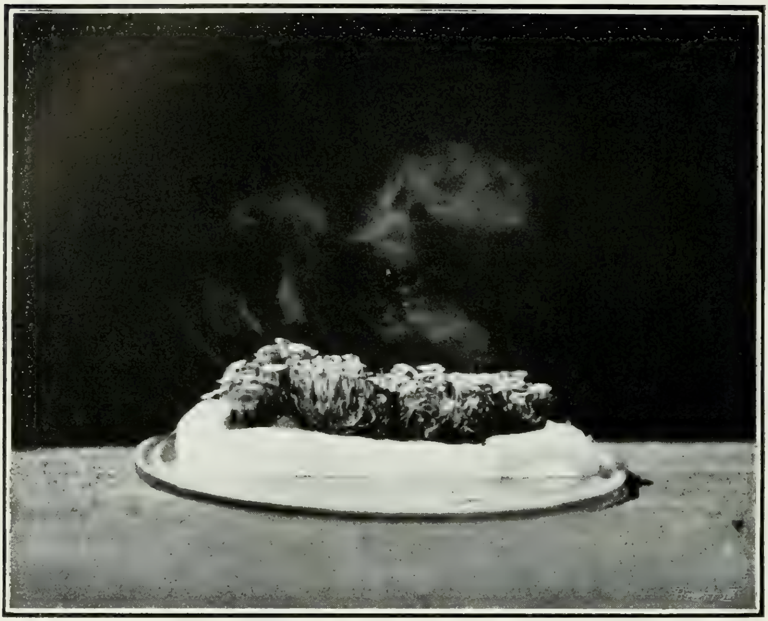


Fig. 111 *bis*. METHOD OF SPORE DISCHARGE FROM APOTHECIA. × ½.

This photograph shows the spore cloud, formed of innumerable ascospores, before it has been dispersed by air currents. The apothecia are those of Sclerotinia sclerotiorum (Lib.) Mass.

After Dickson and Fisher,
Phytopathology, *vol. 13, p. 30, 1923.*

These may become infected and conidia be produced from the mycelium so developed, or the disease may be carried over the winter by mycelium embedded in the tissues of cankers formed the previous season, or by conidia produced from mummies hanging on the tree.

CONSIDERATIONS REGARDING CONTROL.

Control measures consist of the removal of the sources of infection, supplemented by spray treatment, as under:—

(1) Cutting out of infected shoots and cankers on the branches;

(2) Destruction of mummies hanging on the trees or lying on the ground;

(3) Prevention of contamination of fruit during handling and marketing;

(4) Spray treatment.

(1) Removal of infected shoots is necessary, as this prevents the fruits becoming infected from this source; this should be practised preferably in the autumn shortly before leaf-fall commences, for then the dead shoots would readily be seen.

(2) Destruction of mummies is essential, for from these structures the disease spreads in the spring. Mummies should be picked from the trees and from the ground, and burned or buried deeply; but in the case of small fruits, such as plums and cherries, this is impracticable owing to their small size. Nevertheless the destruction of these on the trees should be attempted, those on the ground being dealt with in another manner. The object aimed at in the destruction of mummies is the prevention of infection from spores produced from those on the trees, and, what is more to the point, the prevention of ascospore production from those lying on the ground.

It has been shown that these ascospores are produced in asci borne in apothecia. The production of these structures appears to be governed by the following factors:—(*a*) Weather conditions, (*b*) depth at which mummies are buried in the soil, (*c*) age of the mummies, and (*d*) condition of the soil at the time of their production.

(a) Showery weather preceding and during the time of blossoming, accompanied by mild days and cold nights, appears to be favourable to their production.

(b) They have been produced from mummies lying on the surface, half-buried, and buried to a depth of 8 cm. Their number decreases with the depth in the soil to which they are buried, for no apothecia have been obtained from mummies at a greater depth than this.

(c) The majority of apothecia are produced from mummies of the previous season *(259), (116).*

(d) Soil conditions, in New Zealand at any rate, appear to play a more important part in apothecial production than is generally realised. For the author has shown *(116)* that all specimens collected in the orchards (in 1922) were obtained from hard and compacted soil, such as commonly occurs in areas between rows of trees left untouched by the plough, or round the trees as a result of trampling during pruning operations, whereas on cultivated land in the vicinity none were obtained. Thus it would appear as if compacting of the soil around the mummy were essential to the production of apothecia. The presence of weeds has little effect on their production, as apothecia were equally common on land covered with weeds or weed-free, although those growing among weeds were more advanced.

Two significant facts in the production of apothecia are *(a)* that they are not produced from mummied fruits buried to a depth greater than 8 cm., and (*b*) that they develop apparently only where the soil has been left undisturbed for some months. (This latter statement requires substantiation by experimental evidence; unfortunately the experiments carried out the following season failed in that apothecia did not appear in plots containing either compacted or loosened soil). Therefore where the destruction of mummied fruits is impracticable owing to their small size, the land beneath infected trees should be thoroughly cultivated as deeply as the roots of the trees will allow, and should again be worked well with a cultivator shortly before blossoming commences.

(3) Preventing contamination during picking and packing, and while fruits are in transit. The present system of handling fruit should be modified considerably, as at present fruits may become inoculated in many ways during picking and packing operations. The author would suggest the procedure on p. 97 be followed in so far as picking is concerned. The fruit should be packed directly from the receptacles into which they are picked, and not dumped into a bin. In packing, all fruits showing skin injuries should be rejected. These culls should be packed in separate cases, and, if possible, their sale limited to the nearest local market, or preferably the local factory, should one be in the locality. All fruits intended for long distance transmission should be wrapped in paper similar to that used for wrapping export apples. This would prevent infection during transit from all external sources, or from second-hand cases, thus rendering sterilisation of these receptacles unnecessary, for if unwrapped fruits were packed in these cases infection would be liable to follow, for the author has shown *(111)* that in them conidia of brown-rot may persist in a viable condition for several weeks. Wrapping would limit the spread of brown-rot within the case to those fruits which may develop the disease during transit, and would tend to minimise skin-injuries and bruising, as it is well known that wrapped fruits may be packed more compactly in the case.

CONTROL.

It has been shown that brown-rot may be carried over in cankers formed on laterals and branches, and in mummies hanging on the trees and lying on the ground; furthermore, that infection is not confined to fruit hanging on the tree, but may occur during picking and packing operations, and even during transit, and subsequently in the market. As is well known, brown-rot is the most difficult of orchard diseases to combat, and it must be admitted that by spraying alone the disease will not entirely be held in check.

This necessitates further action, particularly in the direction of minimising infection by the destruction of mummies, cutting out of cankered shoots, and precautionary measures during harvesting and marketing. In short, successful control can be effective only when rigid orchard hygiene is carried out as a preliminary to spraying. If attention is paid to the cutting-out of all cankered shoots during pruning, to the destruction of all mummies, and to the elimination of infection during harvesting, then it may be claimed that infection from brown-rot will be reduced to a minimum, if not entirely prevented.

Carry out pruning operations while the foliage is still on the trees, as at this time all cankers and dead shoots will clearly be seen. This does not necessitate any marked departure from ordinary orchard practice, as autumn pruning is often carried out at this time, notably in Central Otago.

Remove all mummies from the trees and from the ground, and burn them or bury them deeply. Plough in the autumn, and dig under all portions beneath the trees not reached by the plough. Cultivate the land after pruning and before blossoming. This would necessitate the breaking-up of all portions left untouched by the plough, especially those small areas remaining at the bases of trees after cross-ploughing. This would not necessitate any extra work on the part of the orchardist, but merely a possible alteration of the time of spring cultivation. Thin heavily, and thus minimise the danger of infection at points of contact of the fruits.

During picking and packing handle the fruit as little as possible, cull all fruits showing skin-punctures, and be careful to throw out in the orchard any fruits showing signs of brown-rot. Wrap all fruits intended for sale, especially when the market is situated some distance from the orchard. Sterilise daily all picking-tins. It may well be asked whether infection would be prevented during transit by dipping the fruits in some fungicide, or by fumigation. It must be stated that numerous experiments along these lines have been carried out *(263)*, but so far without results that would justify this procedure.

Follow up the elimination of the sources of infection by spraying according to the schedule on p. 88. This will in large part eliminate infection by wind-borne or insect-borne spores which may be carried from adjoining orchards, and, furthermore, will tend to prevent the production of conidia.

Spray applications 1, 2, and 3 prevent blossom and shoot-infection, and tend to stop the development of conidia which later may cause fruit-infection. Sprays 4, 5, and 6 provide developing fruits with an effective coating of fungicide, and thus tend to reduce fruit-infection. If weather conditions are abnormally wet at the time when the fruits are beginning to mature, the number of spray applications should be doubled.

To sterilise fruit-cases several methods of treatment are effective. Immerse cases for one minute in boiling water; or in copper-sulphate solution, 1-100; lime-sulphur solution, 1-50; or formalin solution, 1-320. The cases must be dry before any fruit is packed in them. Immerse tins for one minute in boiling water, lime-sulphur solution, or formalin solution. Do not treat tins with copper sulphate, as they will corrode.

SUMMARY.

1. Brown-rot is a fungous disease attacking leaves, shoots, blossoms, and fruits of apricot, cherry, nectarine, peach, and plum.

2. The causal organism is *Sclerotinia cinerea,* a fungus with two spore stages in its life-cycle.

3. The disease overwinters by means of *(a)* hibernating mycelium in cankers on laterals and branches; *(b)* mycelium in mummies hanging on the tree; *(c)* sclerotia embedded in mummies lying on the ground or buried therein, producing apothecia in the spring.

4. Control measures consist of *(a)* removal of cankered shoots; *(b)* removal of mummies from trees and ground; *(c)* cultivation of soil prior to blossoming and after pruning; *(d)* spraying.

For literature references regarding this disease, see bibliography, p. 349, Nos. *103, 104, 111, 113, 115, 116, 138, 154, 174, 186, 210, 214, 228, 230, 259, 263, 274, 332, 333, 334, 335.*

CHERRY-CURL, Taphrina minor Sadebeck *(269)*.

Syn.: *Exoascus minor* (Sad.) Sacc.
Cherry leaf-curl; cherry leaf-blister.

This disease would appear to have a limited distribution, so far having been recorded only from Germany and the south of England *(272).* In New Zealand it has been found only in a single orchard at Havelock North, Hawke's Bay, and in two orchards at Roxburgh, Otago. In the orchard at Havelock North four cherry-trees are infected—two of the variety Black Tartarian, one Early Purple Guigne, and one unknown variety; in the Roxburgh orchards four trees of an unknown variety are infected. Although in New Zealand the disease has been found only on the cherry *(Prunus Cerasus),* in Germany it has been recorded on an

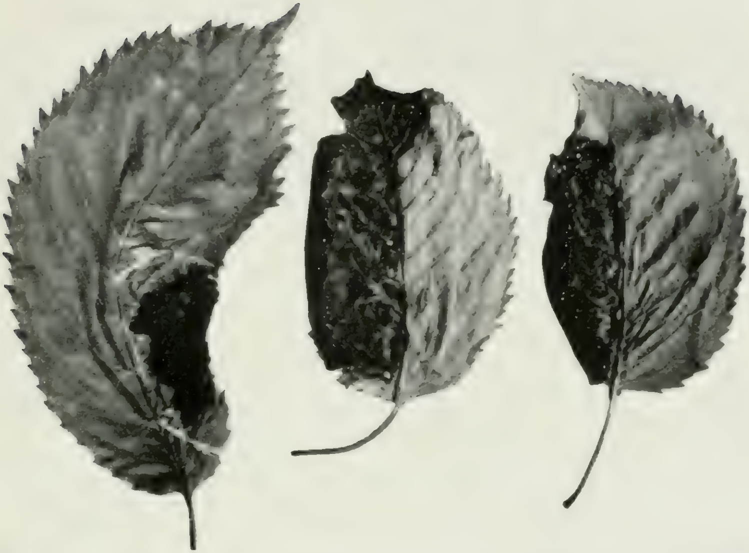


Fig. 112. CHERRY-CURL ON UPPER AND LOWER LEAF-SURFACES. Nat. size.
Photo by Author.

additional host, the ground-cherry (*Prunus Chamaecerasus*). Doubtless this limited distribution is more apparent than real, and the disease mistaken for leaf-curl, as in many publications the cherry is cited as a host of this disease. It differs considerably from leaf-curl in microscopic characters, however, as well as in inability to infect any other hosts than the two mentioned.

It was first recorded for New Zealand by the author (*109*) in 1921.

APPEARANCE AND EFFECT ON THE HOST.

In New Zealand the distribution of cherry-curl is so limited that the disease is scarcely worth more than brief mention here, yet should it spread it may prove to be quite a serious disease of cherries. Fortunately, there appears to be little danger of its becoming widespread. The disease has been known to exist for several years in the three local orchards concerned, and yet has not spread to trees in adjoining orchards nor to adjacent trees in the same orchard.

Cherry-curl infects leaves and shoots. On leaves brightly coloured blistered areas appear (Fig. 112) which so resemble those formed by leaf-curl as readily to be mistaken for it. The leaves then turn brown and fall off. A peculiar feature of the disease is that it does not attack all leaves on a branch, but merely one or two here and there. Then, too, as a rule the whole leaf is not attacked as in the case of leaf-curl, but the infected areas are limited to one half of the leaf, and in consequence the leaf-tissues and petiole are often curved so that apex and base point in the one direction (Fig. 112). Infected branches in a season or two become stunted, make little new growth, and produce few or no blossoms, due no doubt to the effects of partial defoliation.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Cherry-curl is caused by *Taphrina minor,* a fungus belonging to the same genus as that causing leaf-curl, its life-history being similar to that of the latter organism (p. 260). The mycelium hibernates in the dormant buds and in the cuticle of infected shoots, so that when growth commences in the spring the leaves become infected as they emerge from the buds. The mycelium extends into young shoots as they develop, and then penetrates the tissues of the forming buds. Following infection, the mycelium penetrates between the cells, causing them to become enlarged, and so the blistered areas are formed. On the under-surface of these blisters the asci appear, and in them the spores are produced. Although the young shoots are infected, they do not appear to become distorted and discoloured as is the case with leaf-curl, possibly because the mycelium does not penetrate farther than the cells of the epidermis. Spores produced on diseased leaves do not appear to be capable of spreading infection, as the disease in the localities mentioned has not spread to adjacent trees. Moreover, although these infected trees have regularly been sprayed, the disease appears year after year, these two facts clearly indicating that it is perpetuated by perennial mycelium alone. It is probable that trees become infected whilst in the nursery, possibly from buds taken from infected trees, and that by means of this perennial mycelium the disease persists. Such being the case, cutting-out of infected branches would appear to be the only preventive treatment that can be recommended. This presents a certain amount of difficulty owing to the danger of causing excessive gumming, but if cutting-out of branches was performed as soon as growth commenced in the spring this danger would be obviated.

One other disease of the cherry, witches-broom, *Taphrina Cerasi* (Fcl.) Sadeb., caused by a species of fungus belonging to the same genus, is worthy of mention here. It causes large, tufted masses of laterals to appear on the host. Fortunately, so far as the author is aware, it does not occur in New Zealand.

SUMMARY.

1. Cherry-curl infects leaves and shoots, forming distorted and dead areas on the leaves, and causing stunting of the shoots. It is confined to the cherry.

2. The causal organism is *Taphrina minor*. This fungus overwinters by means of hibernating mycelium in dormant buds and in the cuticle of infected shoots.

3. The disease can be combated only by cutting out of infected branches, spraying being ineffective.

For literature references regarding this disease, see bibliography, p. 349, Nos. *109, 119, 269, 272.*

CORAL-SPOT, Nectria cinnabarina (Tode) Fries *(147)*.

Syn.: *Sphaeria cinnabarina* Tode; *Tubercularia vulgaris* Tode.

Coral-spot is a fungus widely distributed throughout the world. occurring as a parasite on the living branches of a large number of hosts, and as a saprophyte on dead branches, twigs, etc., remaining on the tree or lying on the ground or on the floor of plantations and in heaps of prunings. Amongst the many hosts attacked may be mentioned pome- and stone-fruit trees, small fruits, broom, elm, horse-chestnut, maple, mulberry, oak, and silver-birch.

It was first recorded for New Zealand by Kirk *(186)* in 1905.

APPEARANCE AND EFFECT ON THE HOSTS.

This disease is a wound-parasite, and through an injured surface may infect branches, stems, and laterals, and occasionally roots. Its effects on the host vary according to the position of the point of infection and the severity of attack. If, for example, a single branch is infected it may be killed outright in one season. death being preceded by sudden wilt of the foliage, and shrivelling of any fruit that is present; sometimes, however, an infected branch may live for several seasons, in which case it makes little growth, the leaves being smaller than the normal and somewhat yellowish. Although fruit may set on diseased branches it seldom reaches maturity.

Should the stem become infected the tree as a rule is killed outright in the one season. Here infection is followed by sudden wilt of the leaves, and shrivelling of the fruit. These do not fall, but remain attached to the branches until some little time after their death. In such an instance death is invariably preceded by copious gumming.

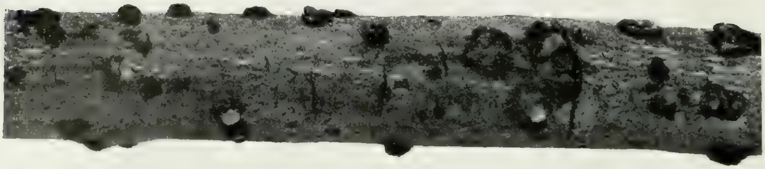


Fig. 113. DEAD APPLE SHOOT WITH FRUCTIFICATIONS OF CORAL-SPOT. Natural size.
The light-coloured spots are pustules of conidia; the dark (red in nature) perithecia.
Photo, W. D. Reid.

Death of the branch or tree may be preceded or followed by the appearance of small sunken cankers, but generally the only indication of the presence of the organism is the dying of the branch, followed by a slight shrivelling of the bark. Shortly after the affected portion has been killed, small bright-pink pustules appear, bursting through the dead bark (Fig. 113). The presence of these pustules, preceded by wilting of the foliage, may be taken as some indication that the damage has been caused by coral-spot; but it is quite possible that the fungus may be present merely as a saprophyte, death of the branch being caused by some other disease, such as valsa-injury, or silver-leaf.

ECONOMIC IMPORTANCE.

Coral-spot attacks only the woody parts of a tree, and in consequence is not readily noticed by the orchardist, whose chief concern is the marketing of blemish-free fruit. Nevertheless, by the destruction of fruiting-branches, and consequent reduction of output, it has proved serious enough to warrant more notice being taken of its presence. Its effects in an orchard in any one season are generally slight, but under certain conditions it may cause considerable loss by killing large branches, or even entire trees. Such a period occurred in Central Otago during the winter of 1919, when many hundreds of trees, particularly apricots, were killed outright *(106)*.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Coral-spot is caused by *Nectria cinnabarina,* a fungus with two spore stages in its life-cycle. The conidial stage is produced shortly after the branch has been killed, but the ascigerous stage does not appear until some time after, usually during the winter months.

As it is so commonly found on dead wood, doubt has been expressed as to whether coral-spot is at any time parasitic, some plant pathologists claiming that its association with a cankered area or killed branch is not necessarily an indication that it has been the

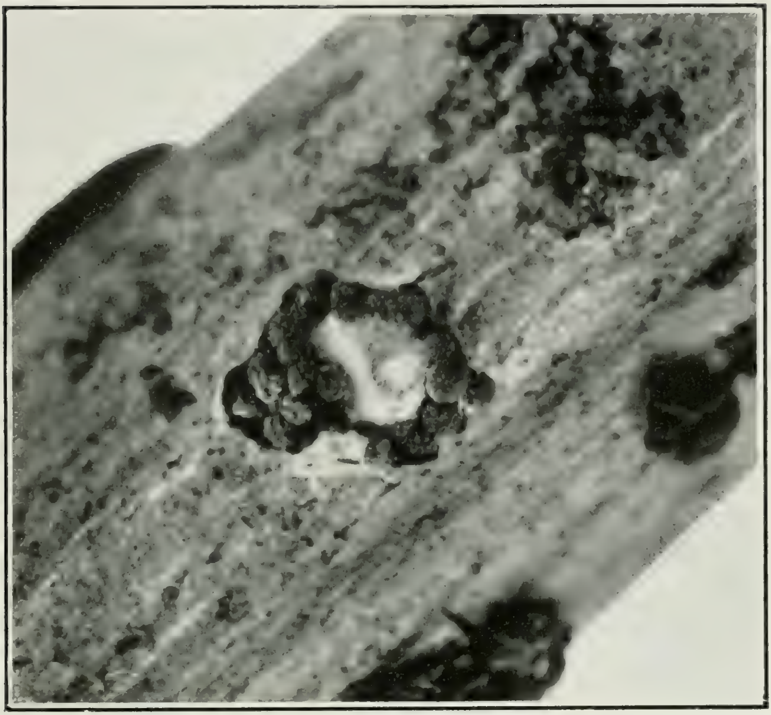


Fig. 114. FRUCTIFICATIONS OF CORAL-SPOT. × 20.
Conidial pustule (light coloured) surrounded by perithecia.

Photo, W. D. Reid.

cause of death, but rather that in such cases it is merely associated with the causal organism, and is living saprophytically on the dead wood. Mayr *(211)*, however, has by a series of experiments proved beyond doubt that, given favourable opportunity, it can become a destructive wound-parasite.

Spores (ascospores or conidia) produced from fructifications upon dead wood on adjacent trees, or from dead sticks, prunings, etc., lying on the ground, are carried by the wind or other agency to dead areas in wounds on the branches of living trees. Line *(203)* has shown that one of the principal methods of penetration is through dead laterals. Here, should conditions prove favourable, the spore germinates and produces an infection-hypha which penetrates the tissues of the dead wood, in which for a time it lives saprophytically, and develops a copious mycelium. Later, the hyphae penetrate to the vessels of the xylem, completely blocking them, and preventing the upward passage of water with food substances in solution, with the result that the branch wilts and dies.

Where entry has been effected on a large branch it may be several seasons before the death of that branch occurs. In such a case a canker is formed which gradually enlarges year after year until the branch becomes girdled, when it dies. The conditions essential to the penetration of the host by the fungus are the presence of abundant moisture, and of dead tissues in the wounded area. Throughout this book the term "wound" has been used in the sense of an abrasion in the bark sufficiently deep to expose the sap-wood. It should be mentioned that entry may be effected through any dead area, such as dead laterals, or dead stubs left as the result of careless pruning; in fact, so long as dead tissue is present in any quantity on a tree there is danger of infection.

Spores alighting on the surface of this dead tissue (whether dead wood, bark, or buds) germinate, and for a time the resultant mycelium lives saprophytically, gradually acquiring a quantity of reserve food, and spreading into the living tissues as described. Here it kills the cells by the secretion of certain toxic substances, utilising the starch-grains stored within these cells, and in their stead depositing a greenish substance—probably some decomposition product—which stains the infected wood a dark colour that is clearly visible when a diseased branch is sectioned.

Upon the death of the limb or branch attacked the organism continues to live as a saprophyte, and from hyphae situated near the periphery of the wood produces closely woven masses of mycelium, which burst through the now dead cortex and appear on the surface as bright-pink cushion-shaped pustules up to 2 mm. in diameter (Fig. 114). A typical pustule consists of a closely woven base of mycelium (stroma) from which upright conidiophores arise (Fig. 115). Each conidiophore is branched, and on short lateral secondary branches minute colourless conidia are borne (Fig. 118). Later in the season, from the same stroma arises a cluster of small, dark-red, flask-shaped perithecia (Fig. 116). Each perithecium opens at its apex by a small ostiolum (Fig. 117, *os*), and contains numerous club-shaped asci, immixed with numerous hair-like paraphyses (Fig. 117, *par*). Each ascus contains eight, one-septate, colourless ascospores (Fig. 119).

The discharge of ascospores occurs only in the presence of abundant moisture, which causes certain portions of the tissues within the perithecium to become gelatinous. As a result the asci are subjected to pressure and the ascospores forced out into the perithecium, where they become embedded in the gelatinous matter. This continues to swell by the absorption of moisture, and there

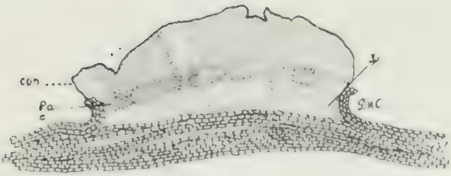


Fig. 115.

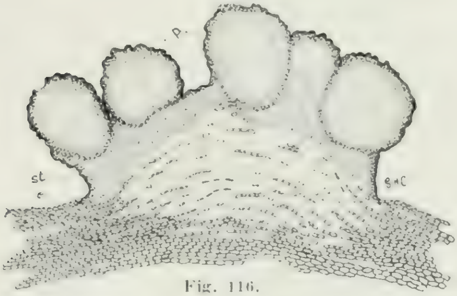


Fig. 116.

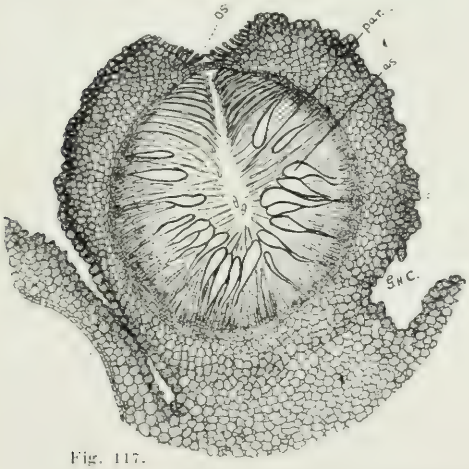


Fig. 117.

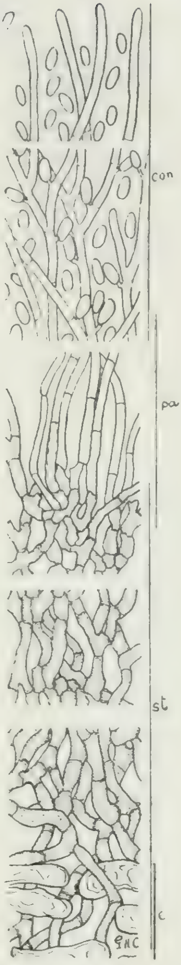


Fig. 118.

Fig. 115. SECTION THROUGH CONIDIAL PUSTULE. × 40.
con. Conidial layer; *pa.* palisade layer; *st.* stroma; *e.* epidermis.

Fig. 116. SECTION THROUGH STROMA BEARING PERITHECIA. × 40.
p. Perithecia; *st.* stroma; *e.* epidermis.

Fig. 117. SECTION THROUGH PERITHECIUM. × 150.
os. Ostiolum; *par.* paraphyses; *as.* asci. Note that the asci are embedded in a mass of hair-like paraphyses.

Fig. 118. SECTION THROUGH A CONIDIAL PUSTULE. × 500.
st. Stroma; *pa.* palisade layer (shown in Fig. 115 as the deeply shaded central portion); *con.* conidiophores bearing conidia on short lateral branches; *c.* plant cells. (In order to enable this section to be shown sufficiently magnified, so that the details may be observed, it has been necessary to omit certain portions; these are represented by gaps in the drawing.) *Original.*

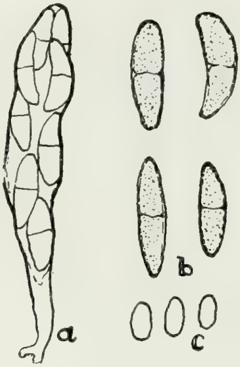


Fig. 119. ASCI, ASCOSPORES AND CONIDIA.
a. Ascus containing spores, × 380; *b.* two-celled ascospores; *c.* conidia, × 500.
Original.

finally issues through the ostiolum a curled tendril, which is white and quite visible to the eye. In this gelatinous tendril the ascospores are embedded, and are freed as the matrix is dissolved away by the rain. The spores then lie on the surface of the stroma until dry, when they are dispersed by the wind. Should they alight on a suitable substratum they may germinate and produce a mycelium, which penetrates the tissues and in turn gives rise to pustules bearing conidia.

REMEDIAL TREATMENT.

From the foregoing it is seen that the organism spreads either from fructifications produced on branches which have been killed by it, or from dead sticks lying on the ground, upon which it may have been living saprophytically. Furthermore, it has been shown that the organism is a wound-parasite, and can attack a tree only through a wounded surface in which dead tissues are present.

Wounds may be due to the following causes:—During picking and pruning operations abrasions are sometimes formed on the limbs, and often branches are split at their junction. Laterals may die as a result of the defoliation caused by attacks of leaf-rust or insects (e.g., bronze beetle); or they may be killed by frost-injury, as was abundantly evident in Central Otago in 1919. Cankers may be formed in shoots and branches by woolly-aphis and other insect pests. Apricots commonly have large crevices in their stems, formed as the result of gumming. All these injured areas afford excellent opportunity for the penetration of the spores.

The following preventive treatment is recommended:—During pruning operations remove all dead wood from the trees. Pick up and burn all prunings, and burn all old heaps of rubbish adjacent to the orchard, thus minimising spore-production. Trim all rough edges of wounds; and cut off stubs of broken branches close to the main stem, so that they may readily callus over. When a branch has been split at the crotch it should be cut out. Deep and narrow crevices should be filled with grafting-wax or some such suitable matrix. Gum-pockets should be cut out. Finally, all exposed surfaces should, as soon as made, be coated with coal tar. All wounds should be tarred annually until such time as they callus over. This is a necessary precaution, as all large wounds have a tendency to crack and expose unprotected wood.

SUMMARY.

1. Coral-spot is a fungous disease attacking the shoots and branches of pome- and stone-fruits, ornamental shrubs, and forest trees.

2. The causal organism is *Nectria cinnabarina,* a fungus with two spore stages in its life-cycle.

3. It is a wound parasite, and is able to infect the host only through the dead tissues of some injured surface; from this the hyphae penetrate to the xylem cells, blocking them and causing a wilt of the infected branch.

4. The fungus overwinters on dead wood on the trees and in heaps of prunings on the ground.

5. Remedial treatment consists of the removal of these sources of infection, and covering wounded surfaces on the trees with coal tar.

For literature references regarding this disease, see bibliography, p. 349, Nos. *106, 118, 147, 186, 203, 211.*

CHAPTER XXI.

STONE-FRUIT DISEASES.

(Continued.)

(a) Fungous Diseases.—Continued.

DIE-BACK, Clasterosporium carpophilum (Lev.) Aderhold *(24)*.

Syn.: *Helminthosporium carpophilum* Lev.; *Clasterosporium Amygdalearum* Sacc.; *Coryneum Beijerinckii* Oud.

California peach-blight; coryneum-blight; fruit-spot; gummosis; peach-scab; shot-hole.

This disease is prevalent throughout New Zealand, occurring on the leaves, fruits, and shoots of almonds, apricots, cherries, nectarines, peaches and plums. It is widely distributed throughout the world, for it has been recorded from Europe, Africa, North America, and Australia. This disease is of historical interest in that it was the principal agent in exterminating the "Maori" peach, once so common throughout the North Island of New Zealand.

It was first recorded for New Zealand by Boucher *(47)* in 1901.

APPEARANCE AND EFFECT ON THE HOSTS.

This disease is abundant throughout on apricots, nectarines, peaches, and plums, but is comparatively rare on almonds and cherries.

On the fruit it first appears in the form of minute spots, purplish in colour. As the spot enlarges it changes to a light brown, becomes more or less circular in outline, and is bordered with a reddish margin. Later the spots become depressed, the margins becoming slightly raised, giving to them a saucer-shaped appearance. These infected portions may then fall away, leaving a small cavity in the surface of the fruit, or may persist as small scabbed areas. In cases of severe infection the spots coalesce, so that the entire surface of the fruit may become affected, but as a rule they are scattered over the surface, more especially on the coloured side, or towards the stalk end. Finally the surface may become seamed with irregular cracks or crevices, and from these small quantities of gum exude, giving to the fruit a very dingy appearance.

The colour, size, and shape of the spots vary according to the host, for on apricots they remain small, highly coloured, and are distinctly scab-like, while on the peach they are frequently confluent, light-brown and depressed, and are frequently accompanied by cracking and gumming.

On leaves, should infection occur early in the season, the fungus produces a conspicuous shot-hole effect. Spots are first circular, light-brown, and surrounded by a dark-brown or reddish margin. Later they become delimited from the healthy tissues of the leaf by a crevice, which encircles the spot. Then the margin of both the spot and the unaffected part of the leaf becomes slightly upturned, with the result that the spot is severed and falls away, leaving a perforation in the lamina of the leaf. Later in the season, secondary infection may occur, resulting in the production of light-brown spots surrounded by a purple border. Late infection is not as a rule followed by perforation of the leaf, for the spot persists until the leaf falls.

On shoots irregular cankers are formed. These at first are about 2 mm. in diameter, circular, slightly depressed, and surrounded by a raised margin (Fig. 121). These areas continue to enlarge until the shoots become girdled and die, giving rise to the characteristic die-back appearance from which the disease derives its common name. Death is usually preceded, accompanied or followed by gumming (Fig. 120). Cankers may be formed in shoots and not lead to the death of the shoot thus infected; in such a case the canker becomes elliptical in shape, and tends to form longitudinal crevices which penetrate through the cortex into the wood, frequently to the pith.

Buds may be attacked and destroyed, this manifestation frequently being accompanied by the formation of a small cankered zone at the base of the bud. Such a condition closely resembles brown-rot infection, and is separable as a rule only by the presence of the fructifications of the causal organism.

ECONOMIC IMPORTANCE.

Fruits may be damaged to such an extent as to be rendered unsaleable, but this is an unusual condition, occurring only in cases of severe infection. Generally the damage to fruit is confined to the formation of numerous small pustules on the surface; these disfigure the fruit and tend to reduce their market price. Moreover, infected fruits remain small, seldom attaining second grade size.

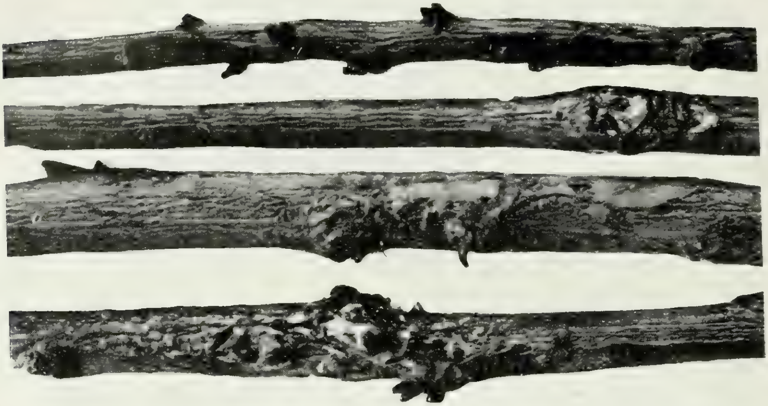


Fig. 120. GUMMING FOLLOWING DIE-BACK INFECTION ON PEACH LATERALS. Natural size.

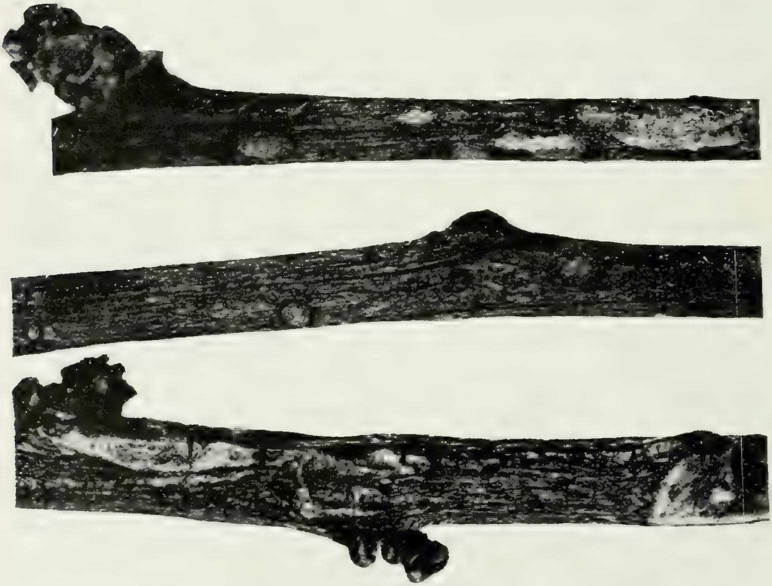


Fig. 121. DIE-BACK LESIONS ON PEACH LATERALS. × 2. Note the fructifications on many of the lesions.

Photos, H. Drake.

Leaves may be perforated to such an extent that their functions are considerably impaired, consequently infected trees make less growth than the normal, carry fewer leaves, and are apt to shed their foliage prematurely.

The most serious effect of the disease is upon the shoots, for where at all prevalent, infection results in a serious die-back, the major number of the laterals being frequently killed back to the previous season's wood. This condition is invariably accompanied by gumming. On other shoots the blossom-buds may be attacked and destroyed, resulting in a decrease in the quantity of the fruit produced. In fact, where preventive measures are not adopted, this disease may become a serious one, second in importance only to brown-rot as a disease of stone-fruits. This is evidenced by its behaviour on the "Maori" peach, many thousands of these seedling trees being killed between the years 1882 and 1889.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Die-back is caused by *Clasterosporium carpophilum*, a fungus with one spore stage in its life-cycle.

Should a conidium be carried to a young leaf, shoot or fruit, it may germinate and produce an infection-hypha which penetrates into the tissues and there branches repeatedly to form a mycelium, the hyphae of which penetrate between the cells, killing them as they advance, and giving rise to the conditions described above. These lesions appear much sooner on the leaves and shoots than they do on the fruits, due no doubt to the fact that fruit-infection is delayed for a time on account of the covering of hairs present on most young fruits. In the tissues the hyphae spread slowly outwards in a radiate manner, and in the older formed portions of the lesions they presently become aggregated into small, closely-woven masses, or stromata (Fig. 122, *st*). From the upper surfaces of the stromata tufts of numerous, slender, coloured conidiophores arise (Fig. 122, *con*). These rupture the epidermis and appear on the surface. From their apices are produced olivaceous, 1-many septate, elliptical conidia (Fig. 122). These may be carried by wind or other agency to developing leaves, etc., in the vicinity, and give rise to further infection.

Infection commences in the spring as the leaves emerge from the buds, from conidia lodged in the vicinity of the buds or between the bud-scales, for McAlpine *(214)* found numerous viable conidia, some actually germinating, in this position. As the leaves expand spots appear on their surfaces, from which further conidia may be produced to infect other developing leaves, as well as developing fruits and shoots.

The fungus may overwinter by means of masses of mycelium embedded in the tissues of the shoots, producing conidia in the

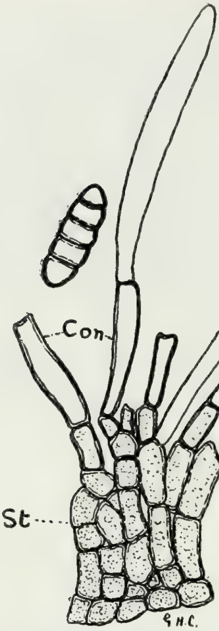


Fig. 122. CLASTEROSPORIUM CARPOPHILUM. × 300.
st. Stroma; *con.* conidiophores, and many-celled conidia.
Original.

spring, or, in the warmer parts of New Zealand, throughout the whole of the year, for McAlpine *(214)* obtained them from shoots every month of the year in Victoria. It appears that the conidia are able to resist desiccation for a considerable period.

Thus there are two possible methods by which the fungus may overwinter:—

(1) By means of conidia lodged in the bud-scales;

(2) By means of perennial mycelium in cankers on the shoots, which may *(a)* remain quiescent until growth commences in the spring, or *(b)* produce conidia throughout the whole of the year.

CONTROL.

Spraying alone has been found to be an effective controllant of die-back, nevertheless spray treatment should be supplemented by the removal of all shoots killed by this disease, not because this would materially aid in control (for numerous small lesions would still be present on living shoots), but because if left they would afford entry to such diseases as coral-spot and valsa-injury.

As the principal source of infection is from spores lodged in bud-scales, a spray applied before the leaves appear would be necessary in order to destroy these. This could be applied at any time during the dormant season, but it would be more economical to delay application until bud movement, the same spray then acting also in the control of brown-rot, leaf-curl, shot-hole, and bladder-plum. This application should be supplemented by one or more later applications, according to the state of the weather and the prevalence of the disease (see schedule, p. 88).

SUMMARY.

1. Die-back is a fungous disease attacking the fruit, leaves, and shoots of the almond, apricot, cherry, nectarine, peach, and plum.
2. The causal organism is *Clasterosporium carpophilum,* a fungus with one spore-stage in its life-cycle.
3. It overwinters by means of *(a)* conidia lodged in bud-scales, and *(b)* hibernating mycelium in infected shoots.
4. Control measures consist in the application of one or more sprays, according to the prevalence of the disease.

For literature references regarding this disease, see bibliography, p. 349, Nos. *24, 47, 214*.

LEAF-CURL, Taphrina deformans (Fcl.) Tulasne *(305)*.

Syn.: *Exoascus deformans* Fcl.
Curl; curly-leaf; leaf-blister; peach-blister; peach-curl.

Leaf-curl is co-extensive with the distribution of its hosts. It is common on peaches and nectarines, but is not confined to these hosts, as in New Zealand it has been found in addition upon almonds and apricots *(119)*, being not uncommon on the latter host.

It is essentially a climatic disease. In dry seasons its effects may be slight, but if during the blossoming time of the host the weather conditions are such that a cold and wet period is followed by a warm, mild and humid one, then infection is usually severe. This severity varies according to the susceptibility of the host, as in a season favourable to the disease certain varieties may suffer little, whereas others may be completely defoliated (see p. 60).

Data as to the relative susceptibility of different varieties have little value, however, as a variety more or less immune in one country may be highly susceptible in another. For example, in Australia the peach varieties Brigg's Red May, Early Crawford, and Solway are all resistant, whereas in North America they suffer severely. Seedling peaches are generally susceptible, as is shown by the virulence of the attack by this disease on the old "Maori" peach at one time so common throughout the North Island of New Zealand.

For explanation of terms, see glossary, p. xi.

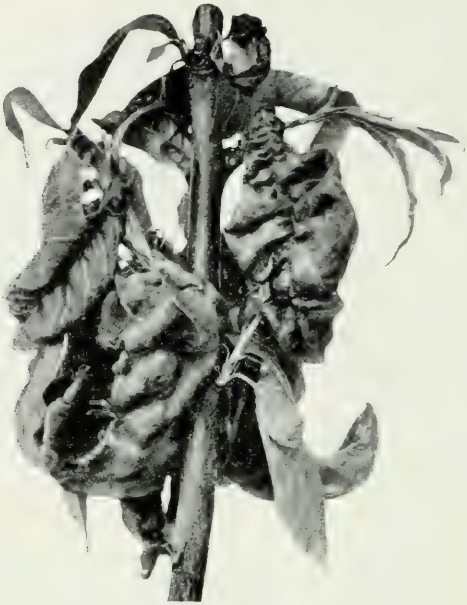


Fig. 123. LEAF-CURL ON PEACH LEAVES. × ½.
Photo, W. D. Reid.

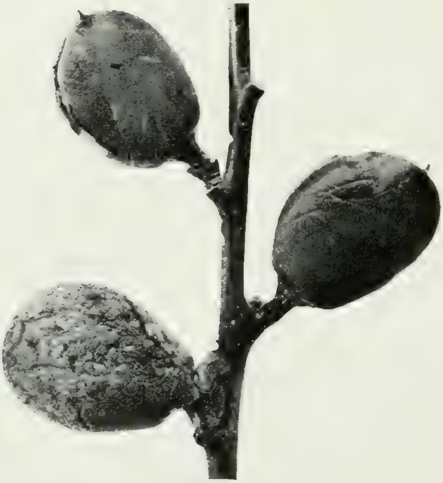


Fig. 124. LEAF-CURL ON NECTARINE FRUITS. × ¾.
Infected fruit (lower left) is scabbed and slightly larger than the normal.
Photo by Author.

Leaf-curl was first recorded for New Zealand by Kirk *(177)* in 1894, but was known to occur here before that date, for it was one of the two diseases responsible for the extermination of the "Maori" peach.

APPEARANCE AND EFFECT ON THE HOSTS.

Leaf-curl infects leaves, shoots, blossoms, and fruits. Infection occurs shortly after the leaves have unfolded from the bud, when they appear somewhat curled and blistered. The mid-rib becomes swollen and curves inwards at its extremity, and the petiole becomes thickened and distorted. This is accompanied by gradual change in colour of the attacked parts. At first green, these change to yellow, and may later become deep-red. At the same time the leaves become much distorted, broadened, and thickened, and are at this stage much folded (Fig. 123), convoluted, and very brittle. On the upper surface of these blistered areas a delicate bloom may be seen, due to the appearance of the fructifications of the causal organism. Finally, infected leaves die and turn brown, and either fall to the ground or remain attached to the lateral, forming small bunches, which doubtless afford suitable shelter for insect pests and possibly the spores of other fungi. Following infection and death of these leaves, others are produced which generally escape attack; but at times, especially if the season is cold and wet, these may in turn be infected, when smaller and less conspicuous blisters are formed; and in exceptional cases leaf-curl may persist on certain varieties during the whole of the growing season.

Infected shoots become somewhat thickened, and often curved and distorted; they also change in colour, often becoming light-green or even yellow. As infection frequently occurs while they are quite small the shoots become stunted, so that the leaf-buds are much closer together than normally; consequently, when leaves are produced they appear so compacted together that the shoot assumes a rosetted form. Infected shoots become weakened, and in many instances may be killed outright. Die-back of the tips of laterals is a common manifestation of leaf-curl. When blossoms are infected the petals become variegated, and are usually larger in size and much crinkled; more frequently, however, the blossoms die and fall to the ground.

Young fruits when infected become much distorted, owing to the affected portions becoming greatly enlarged. Such fruits seldom remain long on the tree, as they become scabbed and cracked, and soon fall. Maturing fruits are commonly attacked—this phase of the disease being more common than is generally recognized—and as a result swollen, irregularly-shaped areas, usually bright-coloured, appear on the surface. These areas are much wrinkled (Fig. 124), and on peaches often appear as if polished, owing to the absence of those hairs which normally cover the surface. They are conspicuous on the fruits of the nectarine, as the bright colouration gives a false impression of maturity. Fructifications may develop on these areas, appearing as a delicate bloom; they are unusual, however.

ECONOMIC IMPORTANCE.

Leaf-curl may reduce the crop in several ways, or it may cause a total loss, according to the severity of attack. (1) Following infection, the foliage may be partially or even entirely destroyed, and as a result a second crop of leaves be produced. This results in a weakened tree, which becomes more susceptible to attack from other diseases. It is doubtful, moreover, whether a full crop will be borne the following season, as when defoliation has been severe little growth is made, and in consequence, owing to the fewer number of fruit-buds formed, the crop is a light one. (2) Again, as a result of defoliation the tree may fail to set any fruit; or, should they set, fruits may not reach maturity, but remain small and stunted, and often be disfigured by large cracks. (3) Laterals may be killed outright, and loss of fruit (otherwise borne on these laterals) consequently follows. (4) Where infection occurs year after year the tree eventually may be killed outright.

On nursery stock defoliation may be followed by the death of the trees, or, at best, growth will be poor and weakly. Then, too, trees thus infected are certain to carry the disease from the nursery to the locality where they are to be planted.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Leaf-curl is caused by *Taphrina deformans*,* a fungus that differs from most other Ascomycetes in having only one spore-stage (Fig. 125) in its life-cycle. It differs again in that the asci are exposed at maturity and not enclosed in a receptacle, and so is considered by mycologists to be a more primitive form.

The leaves become infected shortly after they emerge from the bud, the hyphae of the fungus growing between the leaf-cells; the cells are not killed at this stage, but are stimulated to further growth. The hyphae absorb their necessary food-substances from the leaf-cells, which in consequence become greatly altered; the chlorophyll (green colouring-matter) is absorbed, and the cell-walls become thickened, so that the leaf changes colour and increases in size, becoming broader, thicker, and much blistered. From the

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* This organism is so widely known as *Exoascus deformans* that the author hesitates to use any other name. Unfortunately, no satisfactory classification of this group exists, so that until one is forthcoming he believes it advisable to retain this and the two other species, *T. Pruni* and *T. minor*, under the original generic name *Taphrina*.

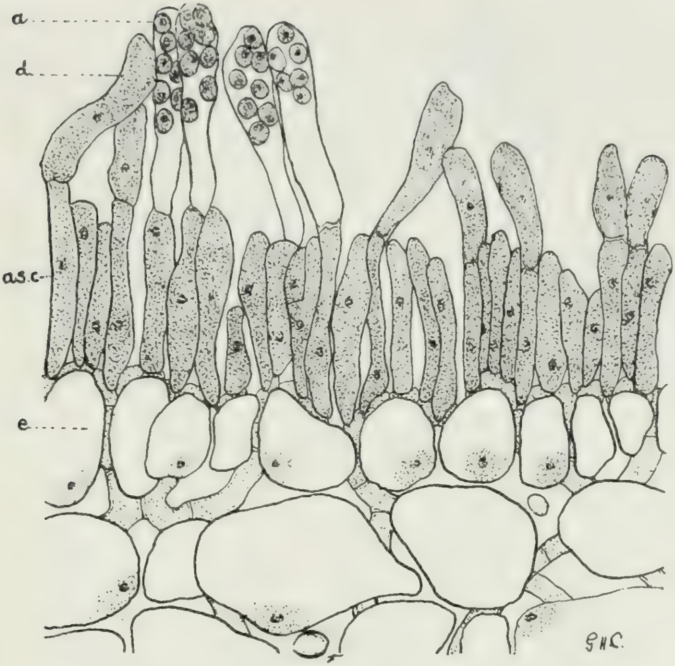


Fig. 125. SECTION THROUGH BLADDER-PLUM. × 500.
a. Asci; *d.* immature ascus; *e.* cells of the epidermis.

Original.

leaves hyphae may grow down the petiole (leaf-stalk) into the shoot to which the leaf is attached, which in turn is infected, and as a result becomes discoloured and swollen. As a rule the current season's shoots only are infected, but on rare occasions the fungus penetrates the tissues of one-year-old shoots.

Following penetration of the leaf-tissues large hyphae develop just below the epidermal cells of the upper surface. From these arise hyphal branches which penetrate between the cells of the epidermis and lie immediately below the cuticle, and there form a closely woven mass of mycelium. From this the asci arise as upright cells beneath the cuticle, and, as they develop, a blister becomes formed owing to the cuticle being raised; this becomes ruptured, and the asci are seen closely packed together (Fig. 125). A mature ascus is cylindrical in shape, is flattened at the apex (Fig. 126), and contains eight, one-celled, colourless spores (Fig. 126).

Finally the ascus becomes ruptured at the apex and the spores are liberated. On germination, these ascospores may either produce

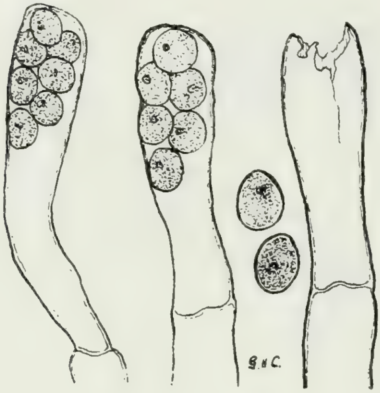


Fig. 126. ASCI AND ASCOSPORES. × 850.
Empty ascus on the right.

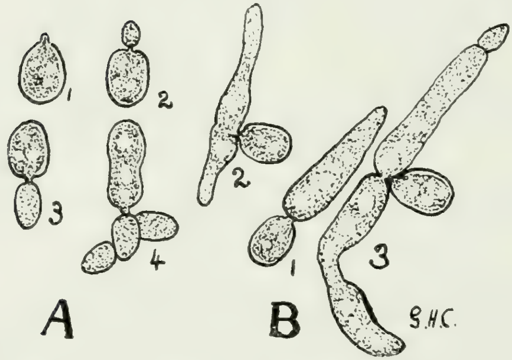


Fig. 127. ASCOSPORES GERMINATING. × 1,000.
A. Ascospores producing conidia (buds); B. ascospores producing hyphae.
Original.

each a short infection-hypha (Fig. 127, B) or give rise to numerous minute conidia by budding (Fig. 127, A). Budding may occur in the ascus either before spore-discharge, or upon the leaf-surface after, when the upper surface of diseased leaves becomes coated with these conidia, appearing as if covered with hoar-frost.

With the production of these spores our knowledge of the life-history ceases. It is not known where the spores remain until they cause infection the following spring, or the method of infection, or the part played by mycelium located in the shoots in the perpetuation of the disease. But from field observations a fair idea as to the subsequent behaviour of the organism may be obtained. Thus it appears that in the majority of cases infection of the leaves as they unfold from the buds is due to spores—whether ascospores or conidia (buds) is unknown—carried over the summer and winter months in bud-scales and crevices in the bark; and that perennial mycelium plays a minor part. This assumption is based on the readiness with which the disease may be controlled by spraying, as a single application at the proper time results in almost complete control. Such a condition could not be obtained were infection due to perennial mycelium, as the spray would not destroy the mycelium, which is protected by the tissues of the shoot. In consequence it is assumed that the spores are lodged in bud-scales and bark-crevices, and that they infect the young leaves as they emerge from the bud; so that a spray applied before the buds unfold destroys these spores, and thus prevents infection. The fact must not be lost sight of, however, that perennial mycelium does play a part in infection, as in certain instances where trees have been carefully sprayed slight infection may persist; or, again, with certain varieties, notably Paragon, this disease cannot be controlled effectively by spraying alone. Infection may be severe, and persist throughout the whole of the growing season. This would tend to show that with this variety, at any rate, mycelial infection is a serious factor, and control in such a case calls for additional treatment.

CONTROL.

It has been found that one spray applied at any time during the dormant season is sufficient to control leaf-curl on most varieties. Now, if this spray is applied at bud movement it serves as a controllant of several other diseases, and also as the first spray in the brown-rot schedule; therefore, where other diseases are prevalent it would be more economical to spray at this period. Several growers have claimed that control is more certain if the spray is applied in the late autumn, after the leaves have fallen, and American workers *(253)* have demonstrated that control may be obtained if the trees are sprayed at this period. The only disadvantage of this method is that where certain other diseases are present, notably brown-rot, it cannot be included in the spray schedule for this disease, so that in reality it becomes an extra spray, applied for the control of leaf-curl alone.

The spray treatment on p. 88 should be supplemented by the cutting out of all infected shoots on those varieties on which the disease persists despite spray treatment. In the spring would be a good time to carry out this operation, for the infected shoots are then readily located.

SUMMARY.

1. Leaf-curl infects leaves, shoots, blossoms, and fruits; causing the leaves to become enlarged and distorted, shoots to become swollen and frequently killed, blossoms to become large, crinkled, and variegated, and fruits to become crinkled and blotched.
2. Leaf-curl infects almonds, apricots, nectarines, and peaches.
3. The causal organism is *Taphrina deformans,* a fungus with but one spore stage in its cycle. It overwinters by means of spores lodged in bud-scales and bark-crevices, and also (but to a lesser extent) by means of hibernating mycelium in the shoots.
4. The disease may, on most varieties, be controlled by one spray application, applied at any time during the dormant season, but preferably at bud movement.

For literature references regarding this disease, see bibliography, p. 349, Nos. *119, 177, 214, 222, 241, 253, 305.*

LEAF-RUST, Puccinia Pruni-spinosae Persoon *(236)*.

Syn.: *Aecidium punctatum* Pers.; *Puccinia Pruni* DC.;
Tranzschelia punctata Arth.
Almond-rust; apricot-rust; peach-rust; plum-rust; rust.

Leaf-rust is common in New Zealand wherever stone-fruits are grown. It appears season after season in the same orchards, first becoming conspicuous towards the end of December.

This disease infects the fruits, leaves, and shoots of the peach and nectarine, fruits and leaves of the almond and apricot, and leaves of the cherry and plum. The aecidial stage of the causal organism occurs on *Anemone, Hepatica,* and *Thalictrum,* but in New Zealand it has been found only on the cultivated *Anemone.* Leaf-rust was first recorded for New Zealand by Kirk *(181)* in 1897, but the aecidial stage was not collected until 1922 *(123).*

APPEARANCE AND EFFECT ON THE HOSTS.

On the under-surface of the leaves it forms small bright-yellow areas, which sharply contrast with the dark green of the leaf, and are visible on the upper surface as discoloured, irregularly shaped spots. In the centre of these yellow areas the uredospores appear as rusty-brown masses (Fig. 129). Finally the leaves turn yellow and fall, from the base of the shoot progressively upwards, till nothing remains but the young developing leaves at the apex of the shoot.

On the fruits small, circular, depressed spots are formed. These become conspicuous as the fruits reach maturity, through the appearance of a reddish border, in which may be seen the uredo-

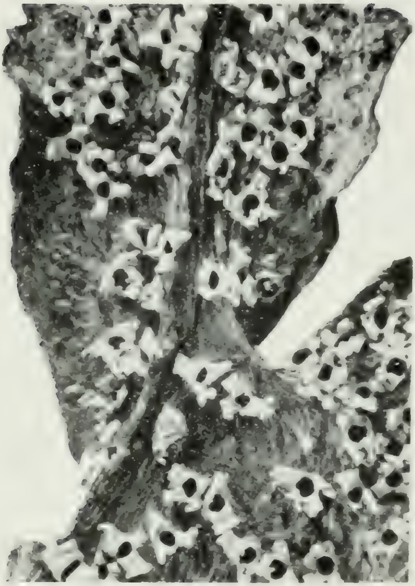


Fig. 128. AECIDIA ON THE UNDER SURFACE OF ANEMONE LEAF. × 2.
Note the broad and expanded margins of the peridia.

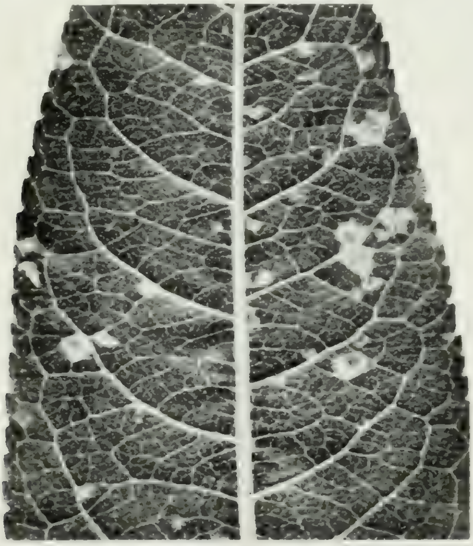


Fig. 129. UREDOSORI ON THE UNDER SURFACE OF NECTARINE LEAF. × 2.
The sori may be seen as minute spots in the centres of the white areas (yellow in nature) which have been discoloured by the mycelium.

Photos. E. Bruce Levy.

spore masses or uredosori (Fig. 131). If a transverse section is cut through the spot, immediately beneath the surface and extending into the fruit 5 mm. to 10 mm. will be seen a compact area somewhat more firm and brighter in colour than the cells of the fruit. This is formed of closely woven masses of hyphae which collectively constitute the mycelium or vegetative portion of the fungus (Fig. 132). The presence of these hyphal masses serves to distinguish fruit-spots causd by this organism from those caused by other fungi. These spots are somewhat common on the fruits of peaches and nectarines, and sometimes appear on the soft outer shell of almonds, but apparently do not occur on the fruits of plums or cherries.

On the shoots of certain varieties of peaches this rust forms small cankered areas, the bark splitting longitudinally, the crevices between being occupied by the uredosori (Fig. 133).

ECONOMIC IMPORTANCE.

Leaf-infection may be followed by premature leaf-fall, defoliation, or even death of the tree, according to the severity of infection and the length of time infection may persist—i.e., whether for one or for several seasons. Where partial defoliation has occurred, the tree becomes weakened and is incapable of carrying a full crop the following season, owing to the fact that the nutrition of the tree is dependent upon the leaves. Where infection persists over a period of several seasons the trees become debilitated, and consequently more susceptible to the attacks of other fungi, such as silver-leaf or brown-rot. Defoliation before the fruit has matured is followed either by the dropping of the fruit, or else by the fruit remaining small and becoming badly disfigured with rust-marks and cracks. On young nursery-stock severe infection and consequent defoliation have resulted in the death of the trees.

Peach and nectarine fruit are sometimes infected, the fruit being frequently rendered unsaleable on account of the disfigurement arising from spots and cracks caused by the fungus (Fig. 131); moreover, fruits so infected are more liable to rot, the cracks offering greater facility for fungous attack. Shoot-infection is followed by the formation of small blisters on the laterals: where infection is severe the laterals may be killed outright.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Leaf-rust is caused by *Puccinia Pruni-spinosae,* a fungus with three spore stages in its life-cycle—namely, aecidiospores, uredospores, and teleutospores; moreover, it is heteroecious—i.e., its aecidia occur on *Anemone,* etc., and its uredospores and teleutospores on *Prunus* spp.

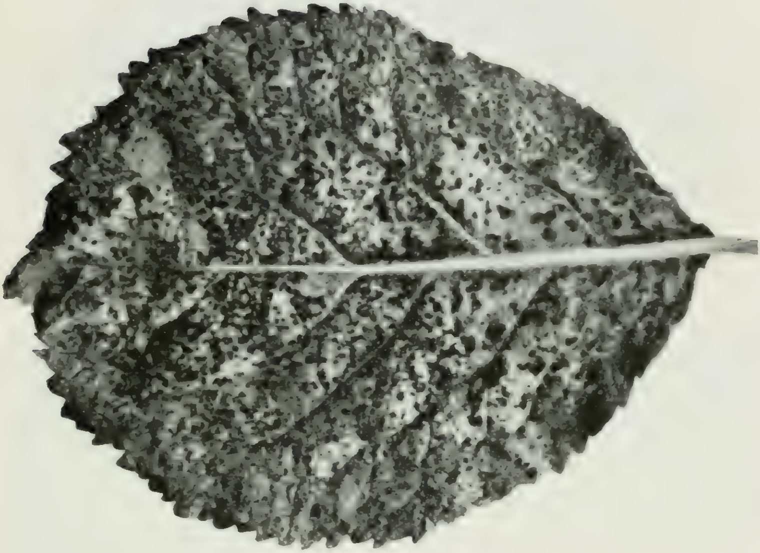


Fig. 130. TELEUTOSORI ON THE UNDER SURFACE OF A PLUM LEAF. Natural size.

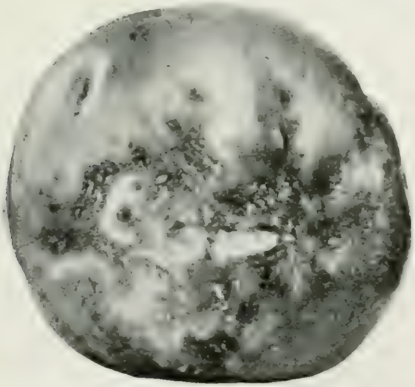


Fig. 131. DEPRESSED SPOTS FORMED ON THE SURFACE OF THE FRUIT OF NECTARINE. Natural size.

The white spots are uredosori; note the distortion and cracking that follows infection.

Photos, E. Bruce Levy.

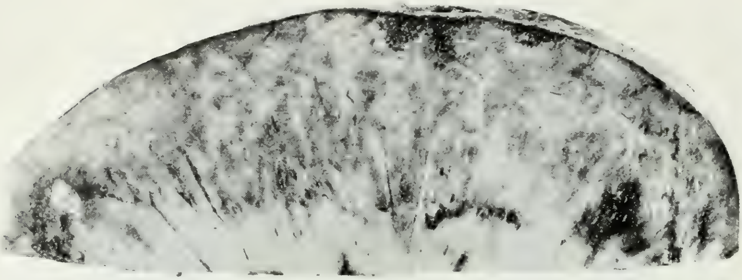


Fig. 132. SECTION THROUGH RUST-SPOTS ON THE FRUIT OF PEACH. × 3/2. The darker areas are compacted mycelial masses.

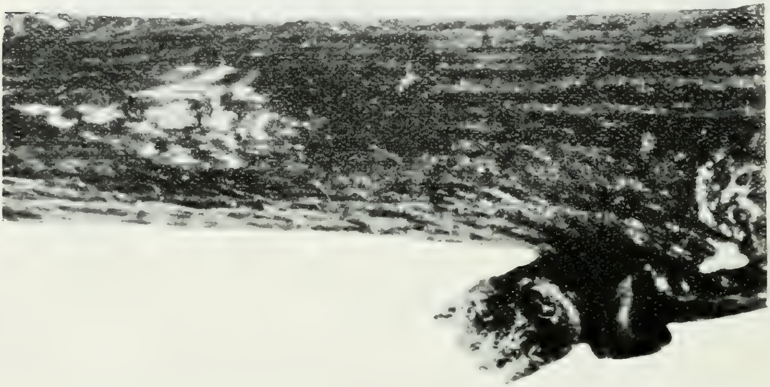


Fig. 133. PUSTULES OF UREDOSORI ON PEACH LATERAL. × 5.
Photos, E. Bruce Levy.

From November onwards small yellowish aecidia—small cup-shaped bodies, peridia (Fig. 134, *p*) filled with spores in chains (Fig. 134, *ch*), make their appearance on certain cultivated species of *Anemone* (Fig. 128). The aecidia are scattered evenly over the leaves, and are readily distinguished by the broad, white, expanded margins of the peridia (Fig. 134, *p*) and the dingy-brown spores. The mycelium is perennial in the tissues of the *Anemone,* and continues to produce aecidia season after season until the host is killed. Infected leaves and stems are distorted and somewhat paler in colour than normal. The attacked plants are of little use to the gardener, as they seldom flower. In fact, so disastrous is this rust on cultivated anemones that it is frequently necessary to grow fresh plants from seed every second year or so.

Should an aecidiospore alight on the leaf of a plum, peach, or other stone-fruit tree, it may germinate and produce an infection-hypha, which penetrates the epidermis and enters the host tissues.

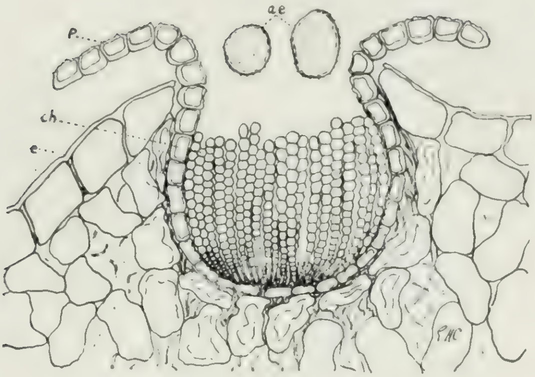


Fig. 134. SECTION OF AN AECIDIUM. × 110.

ae. Aecidiospores × 650; *ch*. chains of aecidiospores; *e*. epidermis; *p*. wall of the peridium.

Original.

Here it branches repeatedly, forming a mycelium, the hyphae of which ramify between the cells of the leaf and, sending small branches (haustoria) into the cells, absorb portion of the contents. The cells thus parasitised are not killed, but apparently the chlorophyll is chemically altered, for the cells change in colour to yellow, forming in mass the minute yellow spots so noticeable on the leaves (Fig. 129).

From the mycelium lying beneath the epidermis upright hyphae are given off, at the apices of which spores are produced. As the spores develop they force the epidermis upwards, forming a small blister, which soon ruptures and exposes the uredospores (Fig. 135, *u*). Uredospores first appear in December, and thereafter during the summer and autumn months are produced in enormous numbers. Each uredospore is capable of infecting the leaves of any other stone-fruit tree in the vicinity, but cannot infect *Anemone*. Uredospores are readily carried by the wind or other agency (insects probably play a part in their distribution) to other trees in the vicinity, and, being covered with minute spines (Fig. 136, *a*), they effectively cling to any surface on which they may alight. It is well to stress the fact that uredospores produced on plum-trees may infect peaches, apricots, etc., and *vice versa*, as it will presently be shown how knowledge of this fact may assist in combating the disease. In the warmer parts of New Zealand uredospores are produced on the leaves of peaches until the middle of June.

Later in the season, from the uredosori or from teleutosori arising from uredospore-infection, a third kind of spore, the teleutospore, is produced (Fig. 136, *b*). Teleutospores are thick-walled,

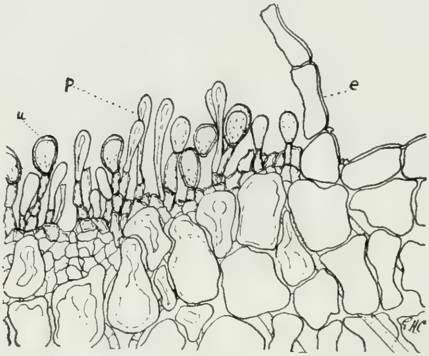


Fig. 135. SECTION THROUGH UREDOSORUS ON PEACH LEAF. × 400.
e. epidermis; *p.* paraphyses; *u.* uredospores.

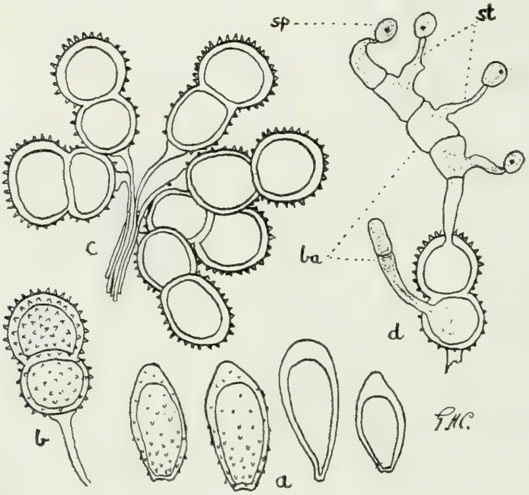


Fig. 136. UREDOSPORES. TELEUTOSPORES AND GERMINATING TELEUTOSPORE. × 500.

a. Uredospores; *b.* teleutospore with pedicel; *c.* group of teleutospores held together by their pedicels; *d.* germinating teleutospore; *ba.* basidia; *sp.* basidiospore; *st.* sterigmata.

Original.

and are covered with a thin chitinous cuticle. They are thus able to withstand extremes of cold until the following spring, when they may germinate and produce short basidia (Fig. 136, *ba*), on which four basidiospores are borne (Fig. 136, *sp*). These are capable of infecting *Anemone* on which they produce aecidia—but they are unable to infect stone-fruit trees. Teleutospores are commonly produced on plum-trees (Fig. 130), but in New Zealand they are comparatively rare on other hosts. The teleutospores are dark chestnut in the mass. Under the low power of the microscope the spores are seen to be aggregated in small spore-balls; higher magnification shows this to be due to the pedicels of a number becoming agglutinated together (Fig. 136, *c*).

In order that the life-cycle may be completed the presence of both *Anemone* and *Prunus* is essential, teleutospores apparently becoming functionless in the absence of *Anemone,* as they can infect only this host. Since leaf-rust is widespread in New Zealand, while anemones are much more restricted in their distribution, it would appear that the latter play but a minor part in the perpetuation of the rust, and that the fungus is carried over the winter chiefly by means of uredospores. This probability is strengthened by the knowledge that the uredospores are capable under favourable conditions of remaining viable for several months—i.e., they will still be alive when the new foliage appears. As most of the infected leaves are deeply buried when the orchards are ploughed, it would further appear that infection is due to spores carried over in the crevices of the bark and bud-scales.

It would appear that in New Zealand the disease overwinters by means of the uredospores, for

1. Anemones are so local in their distribution that as a source of infection they may be regarded as negligible;

2. Uredospores may be collected on leaves so long as the latter remain on the trees; and may be obtained from fallen leaves that have escaped desiccation through the winter months.

3. Uredospores are known to remain viable for several months. Control measures, therefore, must be directed towards the destruction of viable uredospores, and the prevention of leaf-infection by keeping the developing leaves well covered with a protective spray.

CONTROL.

When the leaves have fallen, plough deeply, and dig beneath the trees, turning over all soil not reached by the plough, thus burying the majority of the infected leaves. Spray according to the schedule on p. 88. It is necessary to stress the fact that where leaf-rust control is aimed at, all stone-fruits in the orchard should be sprayed, as if plums are left unsprayed uredospores will spread from this host to other stone-fruit trees in the vicinity.

SUMMARY.

1. Leaf-curl is a fungous disease infecting the leaves, fruit, or shoots of *Anemone,* almond, apricot, nectarine, cherry, peach, and plum.

2. The causal organism is *Puccinia Pruni-spinosae,* an heteroecious fungus with three spore-stages in its life-cycle; the aecidial stage occurs on *Anemone* spp., the uredo- and teleuto-stages on *Prunus* spp.

3. The disease overwinters by means of *(a)* uredospores present in bud-scales and crevices on the bark, or on fallen leaves lying on the surface of the ground; or (*b*) teleutospores on leaves lying on the ground; these latter in the spring germinate and infect the leaves of anemones, from which spores are produced which infect the leaves of stone-fruits.

4. Control measures consist in the ploughing under of fallen leaves, and spraying according to the schedule given on p. 88.

For literature references regarding this disease, see bibliography, p. 349, Nos. *123, 181, 214, 236, 304.*

PEACH-SCAB, Cladosporium carpophilum Thuemen *(311).*

Syn.: Black-spot; cladosporium-freckle; peach-freckle; scab.

This disease is not uncommon in stone-fruit areas throughout New Zealand. It infects the fruits, leaves, and shoots of the nectarine and the peach, and elsewhere *(162)* has been recorded in addition on the cherry, apricot, and plum.

It has a wide distribution, for it has been recorded from North America, Europe, South Africa, and Australia. It was first recorded for New Zealand by Kirk *(185)* in 1904.

APPEARANCE AND EFFECT ON THE HOSTS.

On the fruit it becomes noticeable first in the form of minute, greenish, irregular spots, which later enlarge until they are 5 mm. or more in diameter, become more regular in outline, and much darker in colour (Fig. 137).

These spots may be scattered over the greater part of the fruit, or, as is usually the case, may be confined to the exposed and more coloured part (Fig. 138). They frequently coalesce and form irregular dingy-coloured patches, which may attain to a size of 3 cm. or more. Where infection is severe, the fruits may become scabbed or cracked, the cracks in some cases penetrating to the centre of the fruit; this condition is frequently accompanied by gumming (Fig. 137).

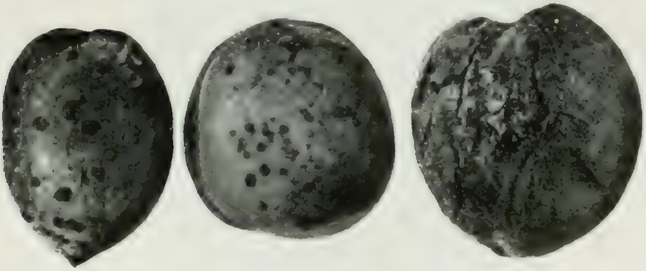


Fig. 137. PEACH-SCAB ON PEACH AND NECTARINE FRUITS. × ½.
Nectarine on left. Final stage of infection shown on extreme right, when crevices have appeared; gum has oozed from these crevices and is visible in the centre of the fruit.

Photo, H. Drake.

On leaves small, irregular, poorly defined spots are formed, usually on the under surface. These may enlarge, become darker in colour, and appear more conspicuous owing to the formation of yellow patches on those portions of the leaf upon which they are seated. These lesions are not confined to the lamina, for they appear equally on the mid-rib and petiole of the leaf.

On shoots the appearance of the disease differs according to the age of the lesion. Newly-formed lesions appear oval in outline, 1 mm. or less in length, brown in colour, and are bordered by a slightly raised margin (Fig. 139). Older lesions are much larger, darker in colour, and distinctly depressed, and are frequently seen to coalesce and form irregular spots, which may be scattered over the shoot or confined to the lower portion. Spots may persist on the shoots for two or three seasons.

ECONOMIC IMPORTANCE.

Severe infection may lead to a total loss of the crop, for infected fruits become much cracked and fall prematurely; or in those cases in which they remain on the tree are not worth picking, owing to their disfigured appearance. Slightly infected fruits possess an unsightly appearance, and consequently command a lower price in the market. Furthermore, infected fruits are more susceptible to the attacks of brown-rot, owing to the presence on their surfaces of cracks, through which the spores of this disease may readily penetrate.

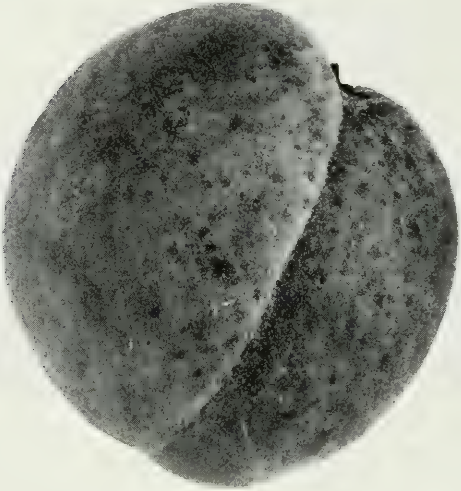


Fig. 138. PEACH-SCAB ON PEACH FRUIT. Natural size.
Slight infection; note that lesions are more numerous towards the stem end.
Photo, W. D. Reid.

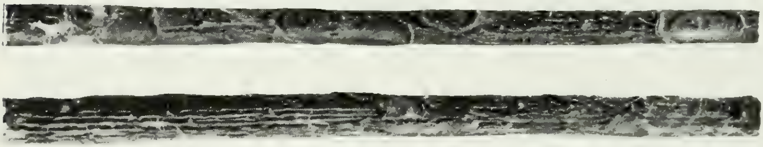


Fig. 139. PEACH-SCAB ON PEACH LATERALS. × 3/2.
Photo, H. Drake.

Leaf infection may be followed by premature leaf-fall, for infected trees usually present an unthrifty appearance, owing to the scanty foliage with which they are clothed.

Shoot-infection in extreme cases may be followed by a certain amount of die-back, but this is not a common manifestation of the disease.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Peach-scab is caused by *Cladosporium carpophilum,* a fungus with one spore stage in its life-cycle. It becomes noticeable on the host about a month or six weeks after the petals have fallen, appearing then on the exposed surfaces of developing fruits, shoots, and mature or immature leaves, in the form of the small spots described above.

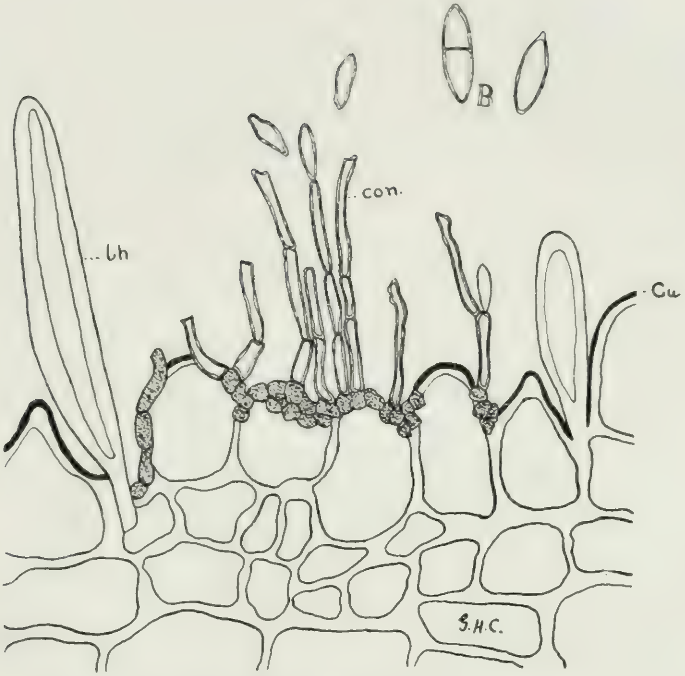


Fig. 140. CLADOSPORIUM CARPOPHILUM.

A. Section through epidermis of peach fruit, showing hairs, *lh.*, cuticle *cu.* (in heavy black) subcuticular hyphae, conidiophores *con.*, and conidia, × 300.
B. Conidia, × 500.

Original.

Should a spore be carried to that portion of the host which it is able to infect, and abundant moisture be present, it may germinate and produce an infection-hypha which penetrates the epidermal cells of the fruit, entering apparently at the bases of the hairs covering the fruit *(155)*, or the subcuticular portion of the epidermal cells of the shoot, where it branches repeatedly to form a mycelium. The hyphae at first are hyaline, but soon become dark in colour, thick-walled, and compacted into closely-woven masses. From these mycelial masses (stromata) conidiophores arise (Fig. 140, *con*); these, during their development, rupture the cuticle, and become exposed, appearing as slender, branched, septate, coloured hyphae, producing acrogenously one to several elliptical, olivaceous one- or two-celled conidia (Fig. 140). It is the presence of these structures, with their attendant conidia, that give to lesions their characteristic olivaceous colour.

In dry weather conidia remain persistently attached to the conidiophores, but in the presence of water they are promptly detached *(175)* and carried in drops of water, wind-blown or spattered, to adjacent fruits, leaves or shoots, where, if conditions prove favourable, they are capable of again producing infection.

The disease appears to be troublesome more on mid-season and late varieties; according to Keitt *(175)* this is because of the following factors:—

(*a*) Conidia are produced shortly after blossoming of the host, from lesions of the previous season on shoots;

(*b*) The incubation period upon fruits ranges from 42 to 77 days; on leaves and shoots from 25 to 45 days;

(*c*) Young peach fruits are more or less protected from infection by the hairy covering, which is highly resistant to wetting. Consequently in the earlier stages of the development of the fruit the spores cannot come in contact with the epidermis and so cause infection, for the hairs prevent the drops of water containing them from penetrating to the epidermis.

Thus, although spores are present about the time the fruit has set, infection cannot occur until the hairy surface of the peach has become more permeable to moisture; even when infection occurs, the growth of the fungus is so slow in the tissues that another 42 to 77 days may elapse before the disease becomes visible. As the fruit of the nectarine does not possess a covering of hairs, it follows that on these fruits the disease will become visible at least a fortnight earlier than on peaches. On leaves and shoots the disease appears about a month earlier than on fruits, for the incubation period of the fungus is lower, being only from 25 to 45 days.

The mycelium in the lesions on shoots produces spores throughout the growing season, and these may infect other shoots, leaves, and fruits in turn; in late autumn this spore production ceases, and the mycelium in these shoots remains quiescent until the following spring, when it gives rise to further conidia. Thus the fungus is perpetuated by means of this hibernating mycelium in the infected shoots, for the conidia are unable to remain viable for more than a few weeks, and no other spore stage is known.

CONTROL.

Two methods of control are possible:—

(1) Removal of the overwintering stage;

(2) Prevention of fruit infection by protecting surfaces with a spray covering.

(1) It has frequently been suggested that infected shoots be removed during pruning operations, so that infection from these sources would be eliminated and the disease exterminated. Unfortunately, owing to the small size of many of the lesions on the shoots, this operation would prove difficult, if not impossible, unless all the shoots on the tree were removed, a procedure which would

result in the loss of the crop. Fortunately such drastic treatment has been found to be quite unnecessary, for the disease may readily be held in check by the application of one or more sprays, provided these are applied at the proper time and at the correct strength. A dormant spray would be useless, as during the winter months no conidia are produced, and the perennial mycelium is partially or wholly covered by the cuticle, and so would not be affected by such a spray.

The schedule on p. 88 is recommended; it is based on field experiments in which complete control has been attained *(175)*.

On nectarines this spray should be applied a fortnight earlier. The first spray is the only one necessary for early varieties; Nos. 1 and 2 should be applied to mid-season varieties, and all three to later varieties in those localities in which the disease is prevalent.

SUMMARY.

1. Peach-scab is a fungous disease attacking the fruit, leaves, and shoots of the nectarine and peach.

2. The causal organism is *Cladosporium carpophilum*, a fungus with one spore stage in its life-cycle.

3. The disease overwinters by means of hibernating mycelium in the infected shoots.

4. Control measures consist in the application of from one to three sprays, according to whether the host is an early, mid-season, or late variety.

For literature references regarding this disease, see bibliography, p. 349, Nos. *162, 175, 185, 311.*

CHAPTER XXII.

STONE-FRUIT DISEASES.

(Continued.)

(*a*) *Fungous Diseases.*—Continued.

POWDERY-MILDEW.

Mildew on stone-fruits is of rare occurrence in New Zealand, but occasionally infected trees are seen, so that it is worthy of brief mention here. Two fungi are concerned in the production of this condition:—

1. Podosphaera Oxyacanthae De Bary *(33)*.

This is occasionally found on the tips of cherry laterals, and elsewhere has been recorded on peach and plum, as well as on numerous other hosts, as, for example, hawthorn and quince. It has a world-wide distribution.

The fungus forms peculiar white patches on the leaf and shoots, the infected portions appearing as if dusted with flour. Infected leaves become strongly curled and distorted, and infected shoots make little growth.

The life-history and control of this fungus is the same as that of powdery-mildew of the apple (see p. 166).

2. Sphaerotheca pannosa Leveille *(201, bis)*.

This fungus is occasionally found on the peach, but is not confined to this host. It has a world-wide distribution.

Leaves, shoots, and fruits are infected, the appearance of the disease on the leaves and shoots being similar to that of the species discussed above. On the fruits irregular circular blotches, up to 10 mm. or more in diameter, are produced; these may coalesce until the whole fruit becomes affected, when it appears as if dusted with flour.

The life-history in essentials is similar to that of powdery-mildew of the apple (see p. 166).

Both fungi may overwinter by means of hibernating mycelium lodged in bud-scales and bark-crevices of infected shoots. They also may overwinter by means of ascospores contained in perithecia embedded in the mycelium covering the affected leaves and shoots, but this condition in New Zealand is so rare as to be negligible.

CONTROL.

Owing to the rarity of powdery-mildew the most economical method of control would be the removal of infected shoots wherever they may be encountered, preferably during the growing season, for they then are readily noticeable. If at all prevalent, the disease may be controlled by one or more applications of 8-100 precipitated sulphur, but where die-back or peach-scab was present, no extra treatment would be necessary, for the spray formulae for the control of these diseases should readily control powdery-mildew, especially if precipitated sulphur were substituted for self-boiled lime-sulphur.

ROOT-FUNGUS, Rosellinia radiciperda Mass.

Although not common on stone-fruit trees, this disease has on occasion been found to attack apricot, cherry, nectarine, peach and plum.

This disease is discussed in detail under pome-fruits, p. 170.

SHOT-HOLE, Phyllosticta Prunicola Saccardo *(267)*.

Syn.: Australian shot-hole fungus.

Shot-hole is widely distributed throughout New Zealand, and in addition has been recorded from Europe, North America, and Australia.

For long, shot-hole was thought to be caused by *Phyllosticta circumscissa* Cke., but McAlpine *(214)* has shown that this fungus is rare in Australia and New Zealand. He states: "It is rather a remarkable fact that, although I have spent more than ten years in investigating the diseases of plants in Australia, that special fungus [*Phyllosticta circumscissa*] has not come to my notice. Over a thousand leaves from various parts of Australia and New Zealand have been subjected to the most critical examination, and whenever the shot-hole was due to a *Phyllosticta*, it was usually found to be *Phyllosticta Prunicola*, and very occasionally *Ph. Persicae* Sacc. It so happens, however, that the sporules [conidia] of the latter are sometimes so similar to those of the fungus described by Cooke in 1883 [*Ph. circumscissa*] that I have come to the conclusion that they both represent the same fungus on different host-plants, and so I have included the 'shot-hole' fungus of Cooke under the previously determined one of Saccardo." Thus he considers *Ph. circumscissa* a synonym of *Ph. Persicae*, a species which is rare in Australia, and so far has not been collected in New Zealand, for on those few occasions in which the author has found fructifications of shot-hole, they have invariably proved to be those of *Ph. Prunicola*.

A shot-hole condition of stone-fruits may be caused by numerous other fungi, as under:—

Die-back, *Clasterosporium carpophilum* (see p. 252).
Peach-scab, *Cladosporium carpophilum* (see p. 272)
Brown-rot, *Sclerotinia cinerea* (see p. 228).

And in North America this condition appears to be caused by *Coccomyces hiemalis* Higgins, *C. Pruniphorae* Higgins, and *C. lutescens* Higgins *(163)*. The first occurs on cherry, the second on plum, and the last on wild plums. Fortunately species of *Coccomyces* have not been found in New Zealand.

Shot-hole was first recorded for New Zealand by Blackmore *(41)* in 1894.

APPEARANCE AND EFFECT ON THE HOSTS.

This disease has been found by McAlpine *(214)* on fruits, shoots, and leaves of the apricot, leaves and shoots of the almond and the peach, and leaves of cherry and plum; in addition, he has recorded it on the leaves of apple, and leaves and fruit of the grape. In New Zealand it has been collected on leaves of almond, apricot, cherry, nectarine, peach and plum, and fruit of the apricot.

On leaves small, brown, circular spots up to 5 mm. diam. are formed. These soon become brittle and fall away. Spots may coalesce and assume an elliptic or even angular appearance, and in extreme cases may destroy the greater part of the leaf.

They are at first slightly depressed, and surrounded by a slightly raised margin, then a crevice appears which separates the dead tissue of the spot from the healthy tissue of the leaf (Fig. 144). The crevice gradually encircles the spot until the dead tissue is completely severed from the healthy tissue, when it falls away (Fig. 141). Later in the season spots may be formed as a result of secondary infection, but perforation does not occur at this period, the dead spots remaining firmly fixed to the lamina (Fig. 143).

On fruit the disease has been observed only on the apricot, where it is readily confused with die-back, owing to the similarity of the appearance of the lesions. Small, circular, somewhat brightly coloured, "scabbed" spots are produced; these are scattered over the surface of the coloured portion of the fruit.

On shoots small, circular or elliptical, elevated brown spots are produced. These may become greyish and fissured longitudinally, giving to old specimens a lacerated appearance.

ECONOMIC IMPORTANCE.

Leaf-infection is the only phase that may be considered at all serious, for fruit- and shoot-infection is so rare as to be negligible. Severe infection may lead to a serious reduction in the leaf-surface,

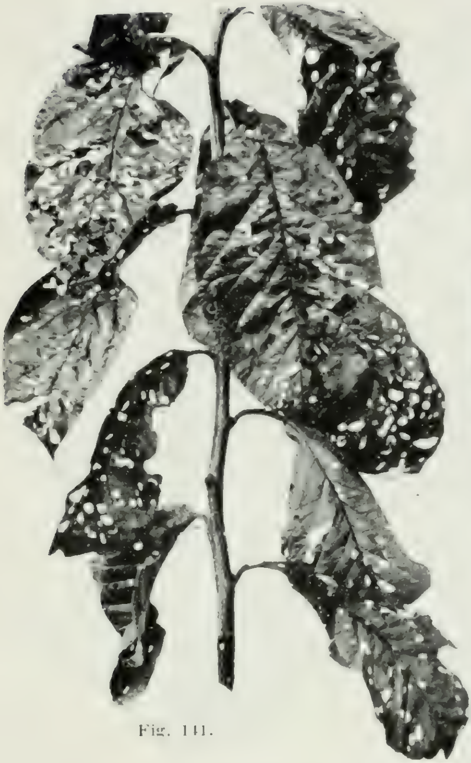


Fig. 141.

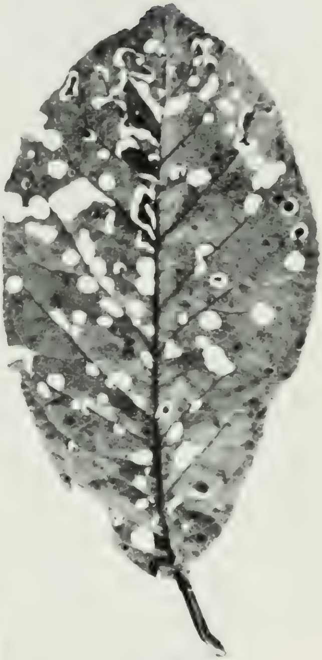


Fig. 142.

Fig. 141. SHOT-HOLE ON JAPANESE PLUM LEAVES. × $\frac{1}{3}$.

Fig. 142. SHOT-HOLE ON PLUM LEAF. × $\frac{2}{3}$.
Typical condition resulting from early infection.
Photos, E. Bruce Levy.

with the result that infected trees become stunted, make little fruiting wood, and are apt prematurely to shed their foliage. Where infection occurs for several seasons the crop is usually light, and the fruit poor in quality and small in size.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Shot-hole is caused by *Phyllosticta Prunicola,* a fungus with one spore-stage in its life-cycle.

Should a spore be carried to a developing leaf it may germinate and produce an infection-hypha which penetrates to the tissues, giving rise to a mycelium, the hyphae of which ramify between and kill those cells with which they come in contact. The hyphae grow radiately from the point of infection, thus forming the circular spots

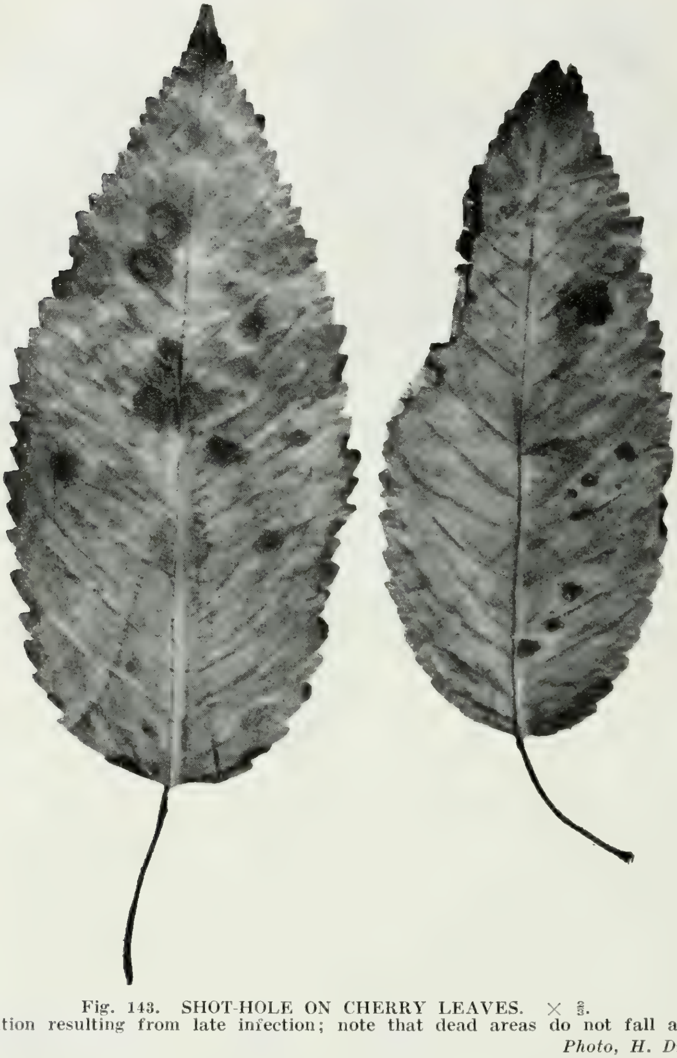


Fig. 143. SHOT-HOLE ON CHERRY LEAVES. × $\frac{2}{3}$.
Condition resulting from late infection; note that dead areas do not fall away.
Photo, H. Drake.

described above. These first-formed spots are cut off from the healthy tissue and fall to the ground where the mycelium of the fungus becomes compacted to form a pycnidium, in which numerous minute, tinted, elliptical, one-celled conidia are formed. These are embedded in a gelatinous matrix, which, in the presence of moisture, swells and is forced out from the pycnidium through the

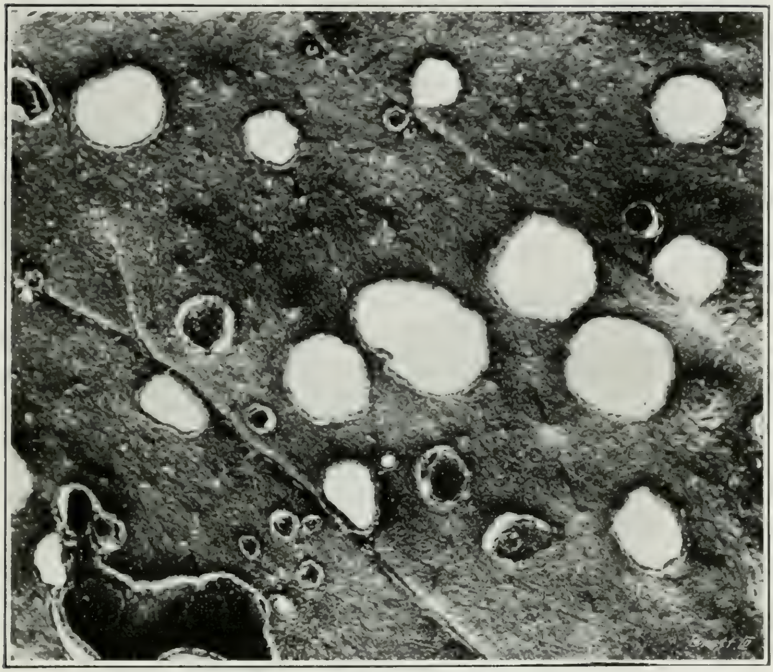


Fig. 144. SHOT-HOLE ON PLUM LEAF. × 8.
Note corky layer formed around margins of perforations.
Photo, H. Drake.

ostiolum, as a slender gelatinous tendril, in which the conidia are embedded. The matrix is dissolved by rain and the conidia liberated, when they are carried by wind or other agency to leaves in the vicinity. Later in the season the spots do not fall from the leaf, but remain attached, so that when the leaves fall to the ground, the mycelium of the fungus is carried with them. Should the leaf escape desiccation, the fungus during the winter months forms pycnidia, from which, when growth commences in the spring, conidia are produced. These, carried to the developing leaves, infect them and give rise to the condition described above, thus commencing anew the cycle of infection.

The fungus also may overwinter in mummied fruits lying on the surface of the ground and in lesions on the shoots.

CONTROL.

As the fungus overwinters in the fallen leaves and fruits on the ground and on shoots on the trees, it follows that if the leaves are ploughed under shortly before the spring, and the trees sprayed at bud movement, the disease will be held in check. Removing infected shoots would prove impracticable owing to the fact that the lesions are so small as readily to be overlooked.

Should the disease prove at all troublesome, a second spray application may be necessary. In fact, the spray schedule recommended for die-back (p. 88) would effectively control this disease, so no additional treatment would be necessary.

SUMMARY.

1. Shot-hole is a fungous disease attacking fruit, leaves, and shoots of the apricot, leaves and shoots of the almond and peach, and leaves of the cherry, nectarine, and plum.
2. The causal organism is *Phyllosticta Prunicola,* a fungus with one spore-stage in its cycle.
3. The fungus overwinters in fallen leaves, mummied fruits lying on the ground, and lesions in shoots remaining on the trees.
4. Control measures consist of ploughing under the fallen leaves and spraying according to the schedule recommended.

For literature references regarding this disease, see bibliography, p. 349, Nos. *41, 163, 214, 267.*

SILVER-LEAF, Stereum purpureum Pers. ex Fries *(147, bis).*

Syn.: *Stereum rugosiusculum* Berk. et Curt.
Silver-blight.

Silver-leaf is abundant in orchard areas throughout New Zealand, and has, in addition, been recorded from Canada, South Africa, Europe, and Australia.

This disease attacks a large number of plants, being common in New Zealand on apples, pears and quinces, almonds, apricots, cherries, currants, gooseberries, nectarines, peaches, plums, as well as many ornamental trees and shrubs, as, for example, broom, lilac, poplar, silver-birch, tagasaste, and willow.

So far as the author is aware, it does not infect indigenous hosts. The disease was first recorded for New Zealand by Blackmore *(41)* in 1894.

APPEARANCE AND EFFECT ON THE HOSTS.

The first indication of the presence of the disease is a silvering of the leaves. These become ashy-grey, tinged with green, and tend to curl slightly at the edges (Fig. 146). Owing to their conspicuous appearance infected trees are readily discernible at some distance, the lighter colour of affected leaves showing in marked contrast to the dark-green of the normal leaves.

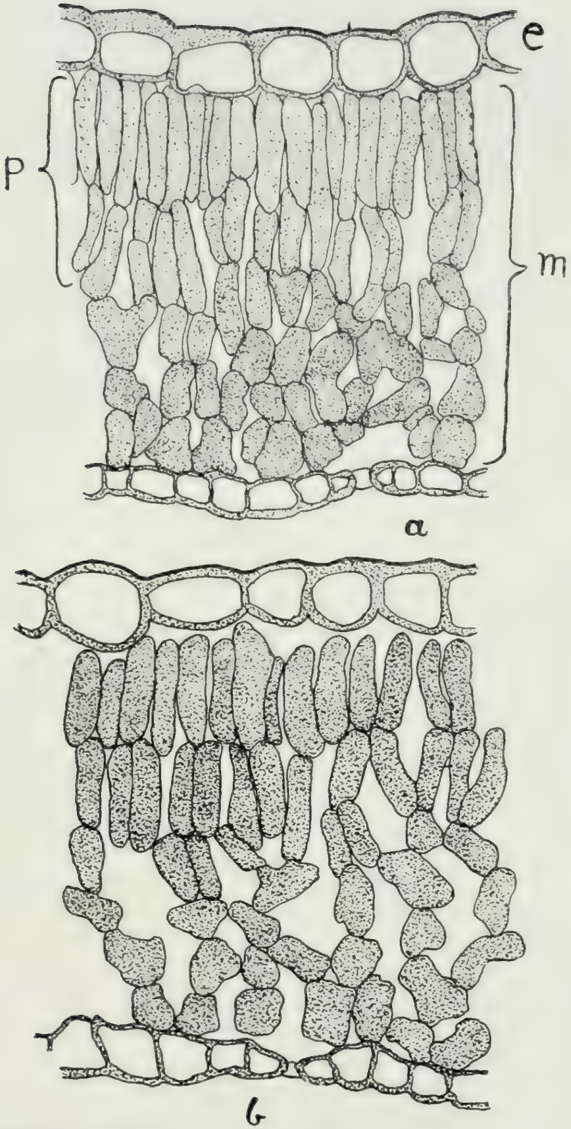


Fig. 145. *a*. SECTION THROUGH HEALTHY LEAF OF PEACH, SHOWING CELLS CONTAINING CHLOROPHYLL (stippled). × 350.
b. SECTION OF A SILVERED LEAF, SHOWING SEPARATION OF EPIDERMIS FROM THE PALISADE CELLS, AND THE DISINTEGRATION OF THE MESOPHYLL CELLS.

Original.

The disease, as a rule, first appears in one or two small branches, and rapidly extends until all the branches of a limb become affected: other limbs begin to show signs of this condition, until finally the whole tree becomes affected. Sometimes the leaves silver simultaneously over the whole tree, but this is not a common manifestation of the disease.

Shortly after the trees show the silvered appearance the branch begins to decline in vigour and dies, either the same season or after one or several seasons, during which time it continues to show leaf-silvering.

Where infection is confined to a single branch it would appear that the causal organism has gained entry through some injury on that particular branch; where infection is general over the whole tree, the organism has probably gained entry through the stem or main roots.

Infection almost invariably is followed by the death of the branch or tree attacked, but occasionally trees have been known to recover. Such trees are by no means immune, for they may succumb to any subsequent attack.

Following the death of the tree the fructifications of the causal organism usually appear (Fig. 148), often on branches which have died before the whole tree has succumbed.

The silvering of the leaves is due to the cells of the epidermis separating from the palisade cells just beneath and becoming somewhat enlarged (Fig. 145), so that air-cavities are formed which prevent the chloroplasts (bodies containing the green colouring-matter of the leaf) from being clearly seen through the epidermis. The other cells of the leaf also become somewhat disintegrated. The separation of the cells is held to be due to a solvent substance produced by the mycelium of the causal organism, which is situated some distance from the leaves. This substance is carried in the water-conduction vessels of the wood to the leaves, where it acts on the middle lamella (Fig. 150), causing the cells to separate from each other.

A silver-leaf condition similar to the one under discussion is sometimes noticeable on fruit-trees and ornamental shrubs. For example, a silver-leaf condition common on lauristinus (*Viburnum* spp.) and *Rhododendron* spp. is caused by thrips.

Drought conditions, alkali soils, and, in fact, many factors under certain conditions may induce a leaf-silvering similar to that caused by this disease; but the starved appearance, frequent dead branches, and the presence of fructifications serve to separate true silver-leaf from the false.

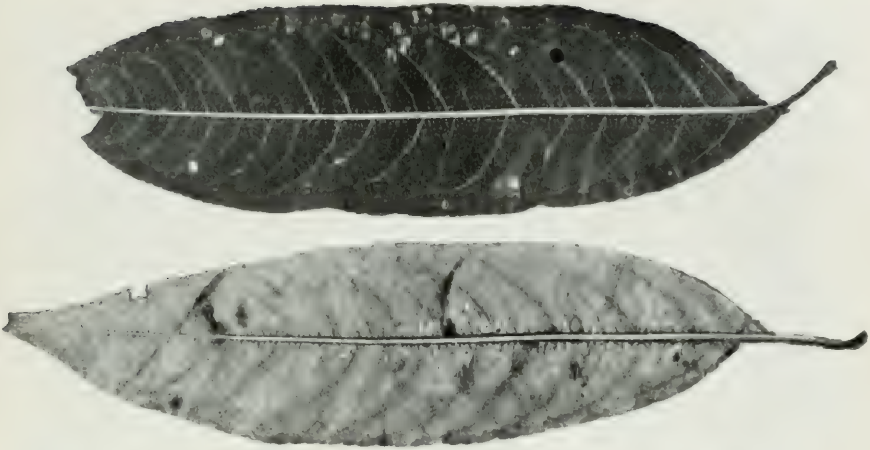


Fig. 146. HEALTHY AND SILVERED LEAVES OF PEACH (under surface). × ⅔.
Photo, E. Bruce Levy.

When a branch is infected with silver-leaf the wood subsequently becomes brown in colour, the discolouration being first noticeable where the organism gained entry through a surface wound (Fig. 147). This discolouration is not so pronounced in young shoots, where it appears in the form of brown streaks which diminish in size and number towards the apex.

ECONOMIC IMPORTANCE.

In New Zealand, silver-leaf infects stone-fruits more severely than pome-fruits, for it causes an annual loss of at least 0.5% in the former, and about 0.1% in the latter. The seriousness of the disease may be illustrated by the following actual instance:—

An orchardist who had 20 acres under peaches was away for four years at the war, during which time the trees were neglected. When he left, four trees in the whole area showed signs of silver-leaf; on his return the leaves were beginning to fall, so that he was unable to estimate accurately the number of trees infected, but believed them to be about 5%. The winter of his return he cut all trees hard back, removing many large branches from each with a saw; the following season 80.1% were found to be infected with silver-leaf, necessitating the destruction of the entire orchard.

This disease probably causes as great a loss as any other orchard disease, with the possible exception of black-spot, but its severity is not readily noticeable, probably because of its gradual onset. A serious feature of silver-leaf is that it cannot be controlled by spraying.

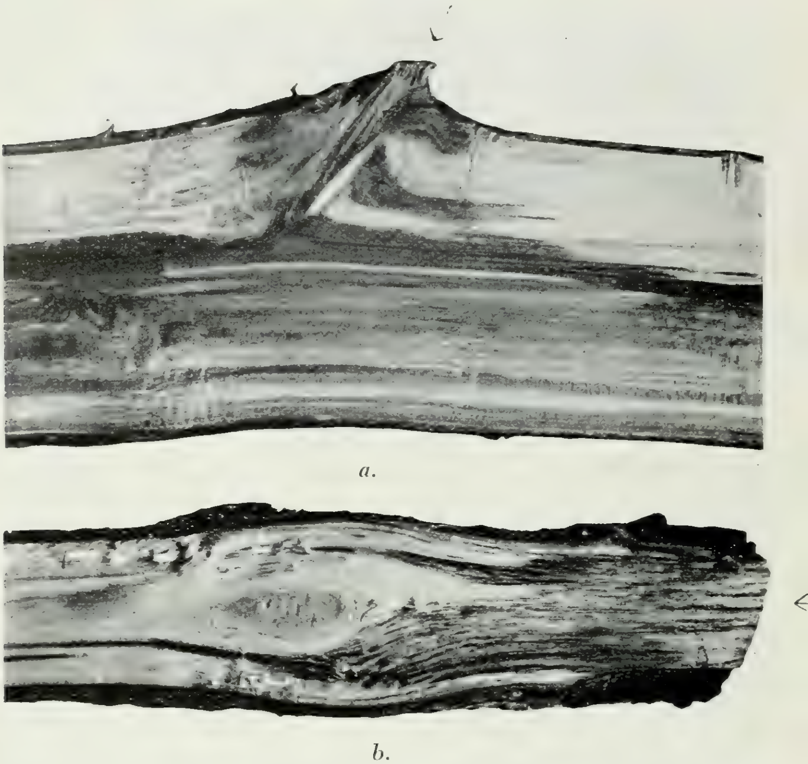


Fig. 147. WOOD INFECTED WITH STEREUM PURPUREUM.

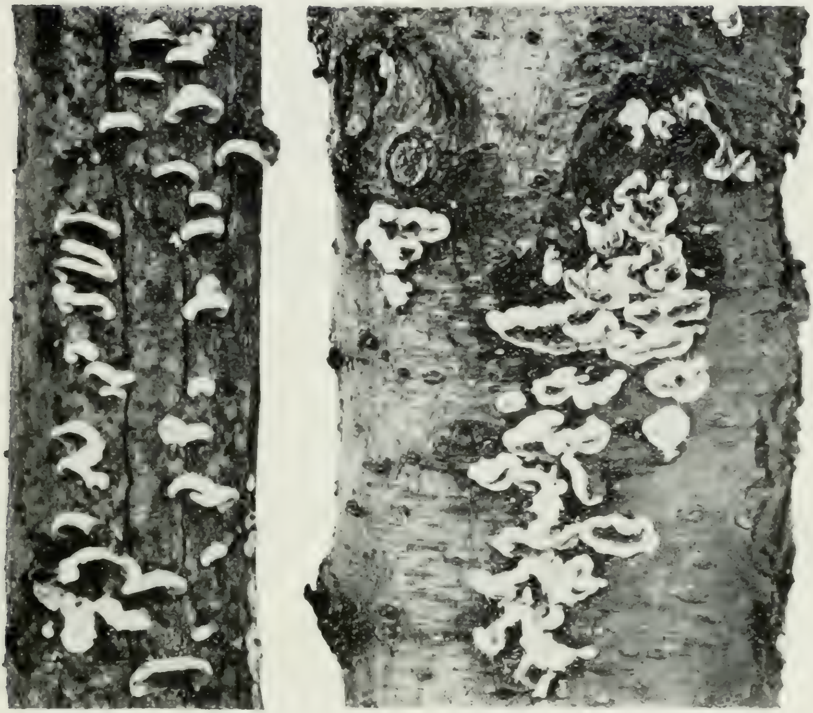
a. Branch of willow, showing area discoloured by the fungus; median section through Fig. 148 *a.;* arrow points to point of entry through stub of branch. × $\frac{2}{3}$.

b. Shoot of peach which was showing signs of silvering in the leaves; arrow points to point of entry through unprotected stub of branch. Natural size.

Photos, E. Bruce Levy.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

For many years the cause of silver-leaf was unknown, this condition being attributed to various agencies, such as unsuitable manures, too heavy pruning, etc., until 1902, when Percival *(234)* suggested that the disease was caused by the fungus *Stereum purpureum,* his reason being that this fungus invariably appeared on trees that had been killed by silver-leaf. His suggestion was not generally accepted by mycologists at the time, largely owing to the fact that no traces of mycelium could be found in the leaves. Subsequent inoculation experiments (in which pieces of the fructifications of *Stereum* were inserted beneath the bark of a tree, and



a. *b.*

Fig. 148. STEREUM PURPUREUM. × ½.
a. On willow branch. *b*. On trunk of living peach tree.
Photos, E. Bruce Levy.

invariably within a short time produced the true condition in the leaves and the wood) have proved beyond doubt that *Stereum* is the cause of silver-leaf *(37)*.

Should a spore be carried by wind to an injured surface of a branch, it may germinate and produce a fine infection-hypha which penetrates to the cells of the wood, where it branches repeatedly to form a mycelium, the hyphae of which penetrate into the killed cells. It is probable that from the tips of these hyphae is secreted a substance which has a solvent action on the cell-walls. This substance kills the cells in advance of the hyphae, and acts on them in such a manner that they may readily be penetrated.

In living branches the hyphae confine themselves to the wood, where they grow towards the apex of the branch much more rapidly than towards the root. When all the cells in the vicinity have been killed, and the branch in consequence has died, hyphae grow out to the surface, and give rise to closely interwoven hyphal masses, having a leathery appearance. This is the fructification, which in appearance is a flat, more or less circular disc, with somewhat upturned margin. It may reach a diameter of 8 cm. or more, but commonly is about 2 cm. Frequently the upper portion grows away from and at right angles to its support, forming a minute shelf (Fig. 151 *a*), when the upper surface is seen to be covered with coarse fibres arranged in differently coloured zones. The free surface of the fructification is smooth, and may range in colour from white, through salmon-pink, to purple; usually, however, it is plum-colour. The free surface is lined with a coloured layer, the hymenium, which consists of basidia and paraphyses packed closely together (Fig. 151 *b*). On the apices of the basidia are four small projections (sterigmata) (Fig. 151, *c, st*), on which the spores (basidiospores) (Fig. 151 *c, sp*) are borne. The paraphyses are sterile basidia (Fig. 151, *b*), which function as spacing organs. The spores are readily detached, and are carried by wind or other agency to trees growing in the vicinity.

Stereum purpureum is frequently found growing saprophytically on dead stumps, poplar and willow, etc., posts and fallen logs, but should opportunity arise for its hyphae to penetrate the living tissues of a host through some wounded surface it becomes an active parasite.

Penetration is more readily effected through wounds freshly made than through those that have been formed for some time, the probable reason being that the presence of bacteria and of other fungi exert an inhibiting influence *(66)*.

It has been noted that occasionally trees infected with silver-leaf recover. This is probably due to the formation of a zone of gummy substances in the periphery of the diseased wood, which, by isolating the infected portion, prevents the further spread of the fungus and cuts off from the conducting vessels the toxic substances which it secretes *(66)*.

Fructifications, and consequently spores, may be produced at any time of the year. These appear more frequently during wet weather, and favour a moist atmosphere, such as surrounds the base of a tree when it is covered by grass or weeds. Spores may be produced at intervals during the life of the fructification, which in many instances persists for several seasons. As previously stated, this fungus can infect living trees only through a wound of some kind. In orchard practice wounds are being constantly inflicted on trees. During cultural operations portions of bark are frequently abraded by chains, swingle-trees, or cultural implements. In picking, branches frequently become broken or split at the forks.

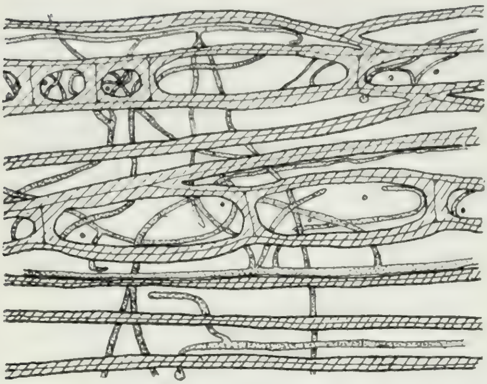


Fig. 149. SECTION OF WILLOW WOOD TAKEN FROM ZONE BETWEEN DISCOLOURED AND NORMAL WOOD SHOWN IN FIG. 148, *a*. × 500. The hyphae are crowded in the region of the medullary rays.

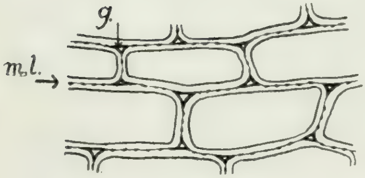


Fig. 150. SECTION THROUGH THE PARENCHYMA OF AN APPLE SHOOT, SHOWING MIDDLE LAMELLA (*ml*) AND GUSSETS OR THICKENED PORTIONS (*g*) WHICH WERE AT ONE TIME INTERCELLULAR SPACES. × 500.

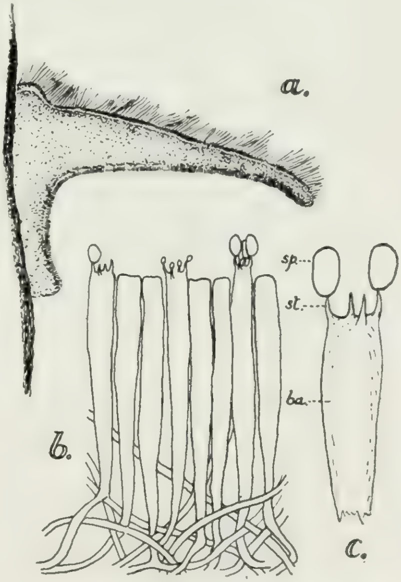


Fig. 151.

Fig. 151. *a*. SECTION THROUGH FRUCTIFICATION OF STEREUM PURPUREUM, SHOWING HAIRY UPPER SURFACE AND SMOOTH LOWER SURFACE. × 6. The lower surface is the hymenium.

b. SECTION OF HYMENIUM, SHOWING BASIDIA AND PARAPHYSES. × 500.

c. DIAGRAMMATIC DRAWING OF A BASIDIUM, SHOWING STERIGMATA (*st.*) AND BASIDIOSPORES (*sp*).

Fig. 151. *a*. *Drawn by E. H. Atkinson.*
Others Original.

In pruning, small wounds are made with the secateurs, and large wounds by the use of the saw. Pests, such as woolly-aphis or cicadas, form cankered areas, which afford excellent opening for the entry of spores.

PREVENTIVE TREATMENT.

As this fungus is spread by means of spores produced on the fructifications (and by this means alone), it would appear as if the removal of these sources of infection would exterminate the disease. Whilst this practice would tend to reduce infection, it would be impracticable to put it into operation, for, in several districts, this fungus is found to be present on broom, willow, and other hosts. For example, in the Tasman and Mapua districts of Nelson, many thousands of infected broom plants may be seen on waste land along the seashore. Yet silver-leaf is not particularly prevalent in those localities.

Therefore it would be advisable to concentrate upon the protection of wounded surfaces, for it is only through these that the fungus may gain entry.

The following treatment is recommended:—

Remove and burn all branches and stumps that are showing signs of silver-leaf or that have been killed by it. Destroy all dead stumps of shrubs and trees carrying fructifications of *Stereum*. It is not sufficient to cut off the fructifications, as the wood is permeated with the mycelium, which will produce more fructifications as soon as conditions are favourable.

Protect all wounded surfaces over 2 cm. in diameter, so that spores cannot enter crevices therein. This first necessitates cutting all broken branches off clean, an operation which should be performed as close to the main branch as possible, so that the wound quickly may callus over. Where a rough surface is left after a saw-cut it should be dressed smooth with a knife. Injuries caused in cultural operations should be dressed smooth, and all loose pieces of bark removed.

Finally, all exposed surfaces should, as soon as possible, be dressed with a wound-covering. The cheapest and most efficient wound-dressing to apply is ordinary coal tar. It is a combined disinfectant (killing all spores present), wood-preservative (protecting the wood against wood-rotting organisms), and protective covering (having the excellent property of pliability), so that it does not crack when the wood expands or contracts, and may readily be applied with a small paint-brush. Wound-dressings should be renewed annually or until such time as the wounds callus over. This is a necessary precaution, as all large wounds have a tendency to crack and expose wood uncovered with any protective coating.

Spraying is useless for controlling silver-leaf, as the mycelium is internal and cannot be reached by sprays. Sulphate of iron, which was at one time freely recommended, also has proved to be ineffective for the treatment of this disease. Moreover, all injections into the tree of substances toxic to the fungus have proved fruitless as a controllant.

Silver-leaf is not spread by the secateurs during pruning operations, numerous experiments having demonstrated this.

SUMMARY.

1. Silver-leaf is a fungous disease attacking the branches, trunks, and roots of pome- and stone-fruit trees, and numerous ornamental and forest trees and shrubs.

2. The causal organism is *Stereum purpureum,* a fungus with one spore stage in its cycle.

3. A secretion produced by the mycelium of the fungus and carried in the conduction vessels to the leaves is the cause of the silver-leaf appearance.

4. The fructifications of the fungus develop on branches of trees that it has killed.

5. Preventive treatment consists in the removal of sources of infection, and especially in immediately covering all wounded surfaces with coal tar.

For literature references regarding this disease, see bibliography, p. 349, Nos. *37, 40, 62, 63, 64, 66, 147 bis, 234, 248.*

CHAPTER XXIII.

STONE-FRUIT DISEASES.

(*Continued.*)

(*a*) *Fungous Diseases.*—Concluded.

SOFT- AND TRANSIT-ROTS.

Four fungi are concerned in the destruction of stone-fruits in transit and in store; these, arranged according to their prevalence, are:—

1. Brown-rot, *Sclerotinia cinerea* Schroet.
2. Blue-mould, *Penicillium expansum* Thom.
3. Rhizopus-rot, *Rhizopus arrhizus* Fisch.
4. Botrytis-rot, *Botrytis cinerea* Pers.

1. BROWN-ROT, Sclerotinia cinerea Schroet.

This disease is dealt with in detail on p. 228. It is the most destructive stone-fruit transit-rot with which the grower has to contend. He may pick and pack fruits from trees apparently free from brown-rot and despatch his cases to the markets, yet when opened up a large number may be found to be infected. In certain cases, indeed, so prevalent is this disease, that over 50% of the fruit forwarded from districts in which the disease is present is condemned on opening up in the markets. Even fruits despatched from Central Otago, from which locality brown-rot is known to be absent, open up on occasion in a diseased condition, especially when they have been forwarded to distant markets.

Two main factors contribute to the wholesale loss from this disease:—

1. Sources of infection.
2. Transit facilities.

1. *Sources of infection* may in turn be grouped under the following five headings:—

(*a*) Infection in the orchard.
(*b*) Infection during picking and packing.
(*c*) Infection from the cases.
(*d*) Infection during transit and whilst in the market.
(*e*) Infection in retail stores.

For explanation of terms, see glossary, p. xi.

(*a*) Infection in the orchard may occur from wind- or rain-borne spores, lodged between the hairs covering the fruit, or in the crevices around the stalk. Under normal conditions these spores cannot infect so long as the surface of the fruit remains dry, but whenever moisture is present infection may occur up to a period of from six to eight weeks after picking, a much longer time than the life of the mature fruit. Such moisture may come from rain on the fruit before or during picking, so that if wet fruit were packed and forwarded, it is highly improbable that it would reach the market in a saleable condition; or from juices expressed from the fruit as a result of skin injuries due to careless handling. Once a fruit has become infected it is capable of infecting in a very short time all other fruits in a case, for as the fungous hyphae penetrate through the tissues, the cells collapse, and pressure being exerted on such fruits from adjacent healthy ones, juices are forced out on to other fruits in the case. Drops of fruit-juices would carry with them spores or fragments of hyphae in suspension. Or the hyphae may grow out from infected fruits and directly penetrate healthy fruits, provided moisture were present at the points of contact.

Were the fruits wrapped singly in paper, as are export apples, the spores of the fungus would be confined to infected fruits, and infection thus minimised; furthermore, wrapping fruits possesses another advantage in that they may be packed more firmly in the case, and thus resist skin injury by bruising, to a much greater extent.

(*b*) Infection through first handling fruits covered with spores is a fruitful source of infection, resulting in a condition described under (*a*). It would be advisable where brown-rot was present in an orchard to first pick infected fruits off the trees before picking healthy fruits, thus lessening the danger of contamination.

(*c*) Infection from cases is possible, for the author has shown (*111*) that from a case that had contained fruit infected with brown-rot one month previously, he was able to obtain numerous spores capable of infecting peaches when inoculated into them. These spores under favourable conditions (described under (*a*)) may cause infection during transit.

(*d*) Infection in transit and market may occur through cases of healthy and infected fruit being in contiguity, the spores being transmitted from case to case in drops of juice expressed from rotting fruits. That such contamination does occur is evidenced by the fact that Central Otago fruits frequently open up in the Wellington and Christchurch markets infected with brown-rot, yet this disease is not present in that locality. Infection in such a case must occur either from such a source or from spores already present in the case, as described under (*c*).

(*e*) Infection in retail stores is a prevalent condition, and is due largely to the careless manner in which the fruits are handled. They may be picked over day after day, and all decaying fruits thrown out, but the healthy fruits put back into the same cases. Such frequent handling, unless done skilfully, is bound to lead to contamination, especially if during handling the fruits are bruised, or punctured with finger-nails, etc.

2. *Transit facilities.*

Unsuitable transit facilities probably favour soft-rots to a greater extent than any other factor.

Railway trucks for the most part are unventilated, the fruit-cases are piled into them *en bloc,* and such trucks treated as ordinary goods, with the result that the fruit is frequently delayed for days ere it reaches its destination. Steamer accommodation is equally bad, cases being lowered to non-aerated holds, where no attempt is made to cool the atmosphere; or they may be piled on deck, subject to washing from any casual water that comes aboard.

2. BLUE-MOULD, Penicillium expansum Thom.

This disease has been dealt with in detail on p. 178. It causes a serious soft-rot of stone-fruits, and, next to brown-rot, is the cause of a greater loss than any other stone-fruit disease. It is a wound parasite, and is able to penetrate only through some epidermal injury. Were wrappings of fruits intended for long distance transmission practised, this damage would be reduced considerably. *All* fruits showing signs of skin injury should rigidly be excluded from cases intended for markets situated any distance from the orchard.

3. RHIZOPUS-ROT, Rhizopus arrhizus Fisch. *(144, bis).*

This is a widely distributed rot of stone-fruits, tomatoes, strawberries, and vegetables. Like blue-mould, it cannot infect other than through some skin injury. Generally, this disease is confined to fruits in store or in the market, but in Central Otago it has proved a serious ripe-rot of apricots, peaches, and nectarines, attacking these fruits on the trees through the punctures of such insects as the earwig. Then, too, it frequently infects fruits liable to splitting of the stone.

So frequent has been the occurrence of this fungus upon fruits on the tree that it has led growers to the belief that brown-rot was present in this locality.

It appears upon fruits in the form of a cottony mould which at first is white, but quickly changes to black, giving to infected fruits a very unsightly appearance. The black colour is due to the fructifications of the fungus. These are in the form of globular sporangia (Fig. 152), borne terminally on long and slender conidiophores. Each sporangium consists of an envelope enclosing many minute, tinted, one-celled spores. When this envelope ruptures the spores are set free, to be carried in drops of water or by wind to other fruits, where, should some skin injury be present, a spore may germinate and produce an infection-hypha which is capable of penetrating to the pulp-cells through the injured surface. The hyphæ penetrate between the cells and shortly produce a rot which at first is brown and quite firm to the touch. Later the cells break down and the fruit is converted into a watery mass.

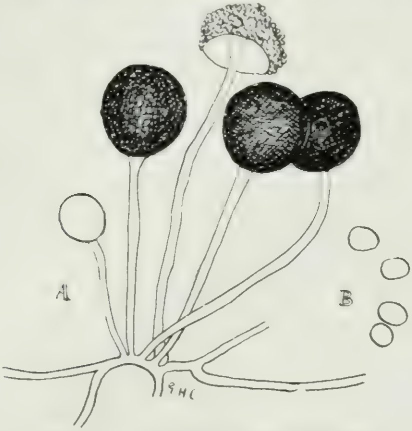


Fig. 152. RHIZOPUS NIGRICANS.
A. Sporangiophores bearing sporangia, one of which has dehisced, × 85.
B. Conidia. × 1,000.

Original.

Owing to its prevalence, this disease cannot be held in check by elimination of infected material. The only preventive treatment that can be recommended with this and other soft-rots which penetrate through skin injuries is to reduce the number of these injuries by more careful handling.

4. BOTRYTIS-ROT, Botrytis cinerea Pers.

Although not prevalent, this fungus sometimes causes a soft-rot of stone-fruits. The method of penetration is similar to that of blue-mould and rhizopus-rot. Consequently remedial treatment would be of a similar nature. This disease is discussed more fully on p. 182.

VALSA-INJURY, Valsa leucostoma (Pers.) Fries *(147)*.

Syn.: *Sphaeria leucostoma* Pers.; *Cytospora leucostoma* Sacc.
Die-back; peach-gummosis.

This disease is fairly general on stone-fruit trees throughout New Zealand, and has been the cause of a serious die-back of apricot and peach trees in Central Otago.

It has been collected on almond, apple, apricot, cherry, nectarine, peach, and plum, and has, in addition, been recorded elsewhere on *Cotoneaster bacillaris (151)*. It has been recorded from Europe, North America, and Australia, and was first recorded for New Zealand by the author *(106)* in 1920.

APPEARANCE AND EFFECT ON THE HOSTS.

The first indication of the presence of this disease is the wilting of a lateral, branch, or limb of a tree, during the growing season (Fig. 153). The leaves on the affected part then turn brown and fall away, leaving the branch bare, in which condition it is quite conspicuous. At or preceding wilting, masses of gum appear, usually at the junction between the dead and living portions of the branch. At a later stage minute pustules appear on the dead areas, and from these are produced long, coiled, slender, gelatinous tendrils, usually light-red or amber in colour.

On laterals that have been killed the bark shrinks slightly, and becomes brightly coloured. On older branches and limbs the border between the living and dead wood is marked by a clean-cut crevice, and the bark on the killed portion becomes slightly darker in colour; but the most characteristic phase of infection is the production of quantities of gum immediately above this crevice.

In short, the sudden wilt of the leaves, accompanied by gum production, may be taken as characters by which this disease may be determined in the field. The presence of the gelatinous spore tendrils is a certain character, but these may not appear until some time after the branch has been killed.

ECONOMIC IMPORTANCE.

As this disease appears only on branches of trees that have been weakened in some manner, it may be claimed that it is not a serious disease. Nevertheless, as it is the direct cause of the death of limbs on such trees—limbs which in all probability would survive in its absence—it may equally be claimed that it is one of considerable economic importance. That it does sometimes become a serious trouble is evidenced by its behaviour in Central Otago in 1919, where it killed outright or seriously damaged many thousands of trees.

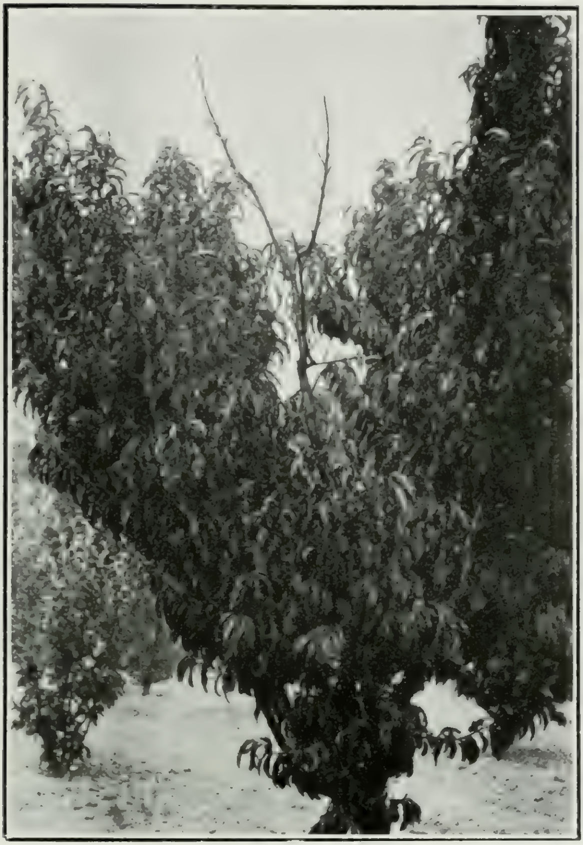


Fig. 153. VALSA-INJURY. Leader of peach tree killed as a result of infection. *Photo by Author.*

In general it may be stated that its attacks are confined to trees that have been weakened by some other agency, so that where trees are well cared for and make strong and vigorous growth there is little danger of its proving troublesome.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Valsa-injury is caused by *Valsa leucostoma,* a fungus with two spore stages in its life-cycle.

Several species of this genus are known to attack stone-fruit trees, consequently this or a similar disease has by different authors been attributed to numerous different species. Comparison of herbarium material shows that the New Zealand species is identical morphologically

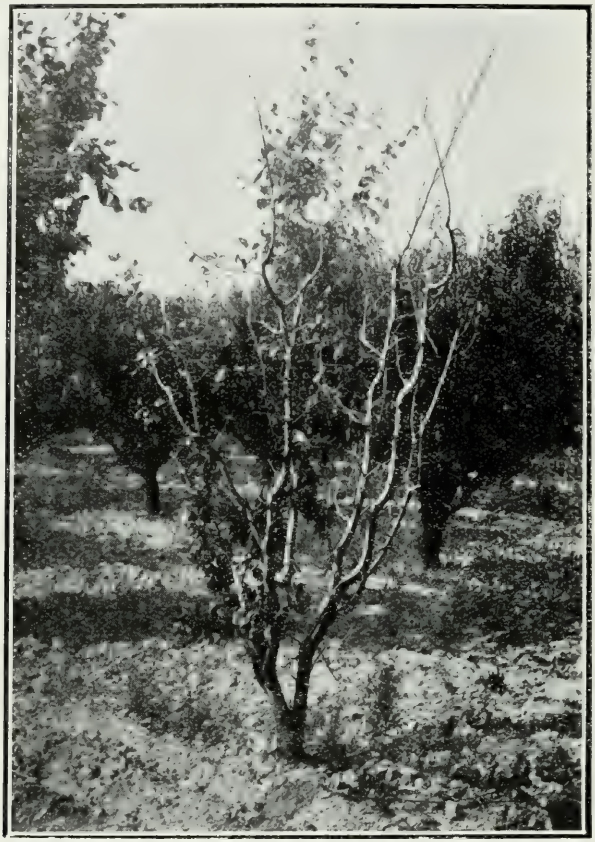


Fig. 154. VALSA-INJURY. Plum tree dying as a result of infection.
Photo by Author.

with the one causing a similar trouble in North America, determined by U.S. Bureau of Plant Industry as being *V. leucostoma;* furthermore, the conidial stage agrees exactly with the description given by Grove *(151)* of *Cytospora leucostoma* (Fig. 155).

Rolfs *(266)* has on cultural differences separated this species into the two following varieties:—

1. *Valsa leucostoma* var. *cincta* (on cherry and peach).
2. *Valsa leucostoma* var. *rubescens* (on apricot and plum).

Shortly after the death of an infected lateral or branch, small black pustules appear, embedded in the dead bark. From these, during showery weather, long gelatinous tendrils are produced. In these tendrils are embedded numerous minute conidia. These are carried to adjacent trees by wind, wind-blown drops of water, insects, or even birds. Should a spore be carried to an injured surface, or a lateral or branch that has been weakened or killed, it may germinate and produce an infection hypha. This penetrates through the wounded surface into the dead tissues, or in the case of a weakened lateral may penetrate through a bud into the living tissues. In the dead tissues it develops a mycelium which lives saprophytically for a time and then gradually spreads to living tissues. In the living tissues the hyphae penetrate to the conduction vessels, blocking them and preventing the upward passage of water, consequently wilt and death of the infected branch or lateral follows.

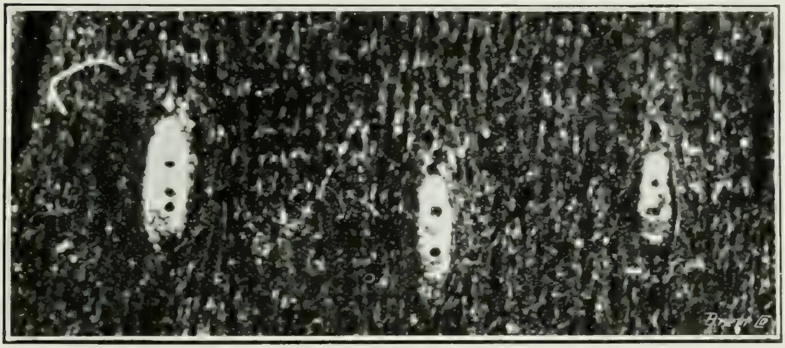


Fig. 155. WHITE DISCS CHARACTERISTIC OF VALSA LEUCOSTOMA. × 15. The black spots in the centre of the discs are the openings (ostiola) of the pycnidia.

Photo. H. Drake.

In the dead tissues the fungus lives saprophytically. After a time closely woven hyphal masses are formed which give rise to pycnidia, several of which (1-5) are arranged in a compact group, attaining a diameter from 2-4 mm., being, in fact, quite visible to the eye as the minute black pustules mentioned above. Each pycnidium is provided with a long neck, the centre of which is pierced by the ostiolum (Fig. 155).

Within these structures the conidia are developed; they are embedded in mucilage, which in the presence of water swells and is forced out through the ostiolum in the form of a long, coloured tendril, which may attain a length of 25 mm. or more. The spores are freed through the mucilage being dissolved by moisture, and are carried to other trees in the vicinity. On larger branches the perithecial stage of the fungus may be developed. This is similar in appearance to the pycnidial, save that a greater number of perithecia occur in any one stroma. Within them are numerous asci, each containing eight one-celled, colourless spores. The perithecia are filled with mucilage, and from them also tendrils containing ascospores (either free or contained within the asci) are produced. The ascospores may be distributed in a similar manner and also may infect laterals or branches should conditions be favourable.

It has been mentioned that trees weakened in some manner are susceptible to attack, even though no injured surface is present. This was evident in 1919 in Central Otago, for it was found that in practically every case infection of the tree arose through laterals that had been killed by spray- or frost-injury. The fungus had spread from these dead laterals to the larger branches.

Other factors tend to weaken the tree and facilitate infection. For example, apricots growing in light stony ridges are frequently severely damaged by valsa-injury; again, trees growing in hollows subject to flooding are frequently found to be infected. In a few instances trees have been defoliated with certain spray solutions, and many of these trees have been found to be infected.

The fungus is able to live for a considerable time on dead wood either on the tree or lying on the ground, and, wherever conditions are favourable, produce spores in abundance.

REMEDIAL TREATMENT.

As this fungus is able to penetrate into healthy tissues through (*a*) dead laterals, (*b*) injured surfaces in laterals or branches, (*c*) buds and laterals that have previously been weakened by other agency; and as it is able to overwinter on dead wood on the tree or lying on the ground, it follows that remedial treatment would consist in

(1) Removing the sources of infection;

(2) Protecting wounded surfaces;

(3) Removing from the tree all dead laterals and wood;

(4) Removing those factors which tend to inhibit the normal growth of the trees. Therefore:—

1. Cut out and burn all infected laterals and branches. Burn all heaps of prunings, for the fungus may frequently be found on dead branches in these heaps.

2. Paint all wounded surfaces with coal tar.

3. During pruning operations cut out all dead laterals and wood. This should preferably be done in the autumn whilst the leaves are still on the trees, for at this time all dead wood would be readily noticed.

4. Prune weakly trees hard back, and thus induce vigorous growth. Drain areas in which water tends to lie. Where irrigation is practised this work should be undertaken in a systematic manner, proper channels constructed, and water led off the land and not allowed to accumulate in pools.

SUMMARY.

1. Valsa-injury is a fungous disease attacking laterals and branches of the almond, apricot, cherry, nectarine, peach and plum.

2. The causal organism is *Valsa leucostoma,* a fungus with two spore stages in its cycle.

3. It gains entry into the healthy tissues of the host through (*a*) wounds; (*b*) dead laterals; (*c*) weakly growths on living trees weakened through some other agency.

4. The disease overwinters on dead wood on the tree, or lying on the ground.

5. Remedial treatment consists in (1) removal of sources of infection; (2) treatment of wounds; (3) removal of dead laterals from the tree; and (4) inducing healthy growth in the tree.

For literature references regarding this disease, see bibliography, p. 349, Nos. *106, 147, 151, 266.*

CHAPTER XXIV.

STONE-FRUIT DISEASES.

(*Continued*).

(*b*) *Bacterial Diseases.*

ROOT-KNOT, Phytomonas tumefaciens (Sm. et Townsd.) Committee S.A.B. *(39)*.

Syn.: *Pseudomonas tumefaciens* (Sm. et Townsd.) Stev.;
Bacterium tumefaciens Smith et Townsend;
Dendrophagus globosus Toumey.
Crown-gall; crown-knot; hairy-root; root-gall.

Root-knot is a disease that came into prominence in 1917, owing to its presence in Australia resulting in an embargo being placed by the New Zealand Department of Agriculture against the importation of Australian fruit-trees into New Zealand.

Although it had been in New Zealand many years previously, being first recorded by Boucher *(46)* in 1900, it was not until 1912 that it was considered to be at all a serious disease.

It has been collected on young trees of apple, pear and quince, almond, apricot, cherry, nectarine, peach and plum, and has been recorded on many additional hosts, as, for example, beet, chestnut, grape, honey-suckle, hop, lettuce, lucerne, parsnip, poplar, rose, turnip, willow, and numerous others *(285)*. The disease has a wide distribution, for it has been recorded from Europe, North and South America, South Africa, and Australia.

APPEARANCE AND EFFECT ON THE HOSTS.

The disease in nature is confined to the roots and crowns of infected plants. It may produce two conditions, widely differing from each other in appearance. These are:

1. Wart-like tumours on the roots or crown (Fig. 156).
2. Masses of hair-like or fibrous roots, from localised areas on the main roots or crown.

1. The tumours—the presence of which lend to the disease its common name—may be soft or hard, and range in size from 5 mm. to 12 cm. or more, for on old trees they have been known to attain to a diameter of 60 cm. At first they are small, pallid white, and

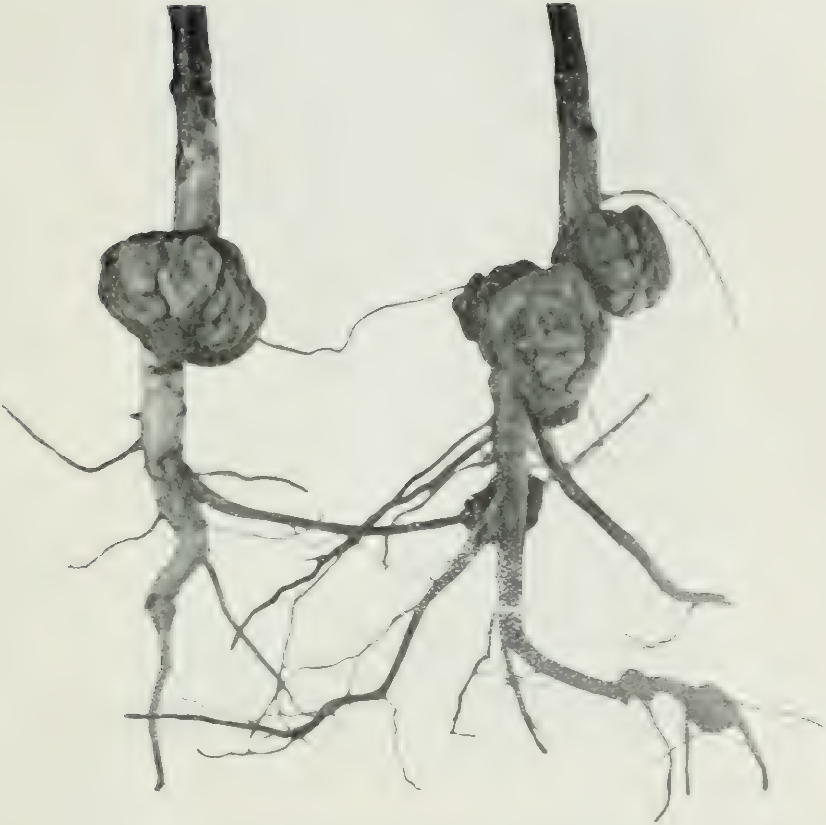


Fig. 156. ROOT-KNOT ON PEACH SEEDLINGS. × ½.
Photo. H. Drake.

quite soft, but as they continue to increase in size they assume a darker colour, and finally become hard and woody, and the exterior becomes roughened and frequently much convoluted. Roots often spring from the exterior of such tumours, giving rise to the second or hairy-root condition. Each growing season further increase in size occurs, the surface becomes greatly roughened, and the tumours tend frequently to slough off several of the outer layers of cortical tissue. Finally, large portions of tumours may break away from their point of attachment.

2. The second or "hairy-root" condition consists of the appearance of numerous fine roots growing in tufts from the main roots or stem. These fine roots may spring from the surface of tumours.

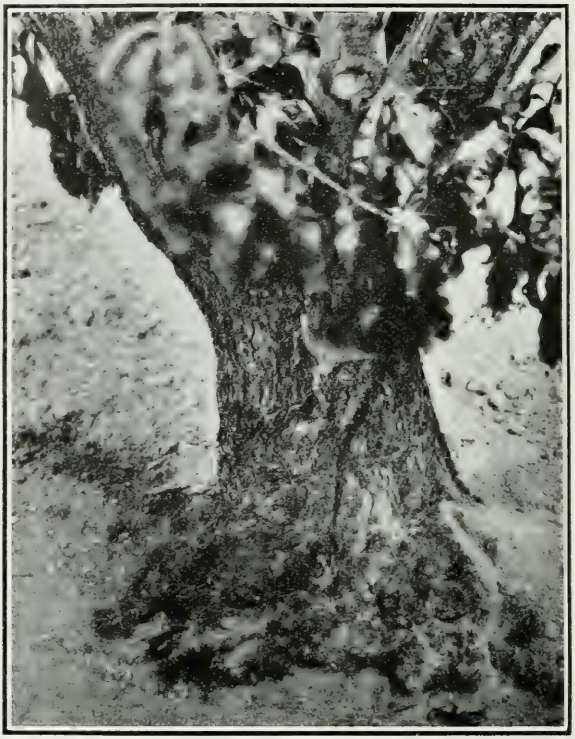


Fig. 157. ROOT-KNOT ON PEACH TREE.
Crown exposed to show the large tumours at the base of the tree shown in Fig. 159.
Photo by Author.

but usually arise from flattened tumours, which, owing to their small size, are readily overlooked. These numerous roots are produced from adventitious buds situated in the cambial layer *(157)*. This hairy-root condition assumes four distinct forms, which have been described in detail *(157)*, but further division is unnecessary here.

ECONOMIC IMPORTANCE.

This is a serious disease of nursery stock, for young trees suffer more severely than do older ones. In fact, it may be claimed that in New Zealand infected trees in the orchards suffer little, if any, detrimental effect from the presence of these tumours on the roots (this matter is discussed more fully under considerations regarding control).

Severely infected nursery stock is stunted and frequently killed outright; as the disease does not occur in New Zealand nurseries this phase of the trouble may be ignored; but its presence

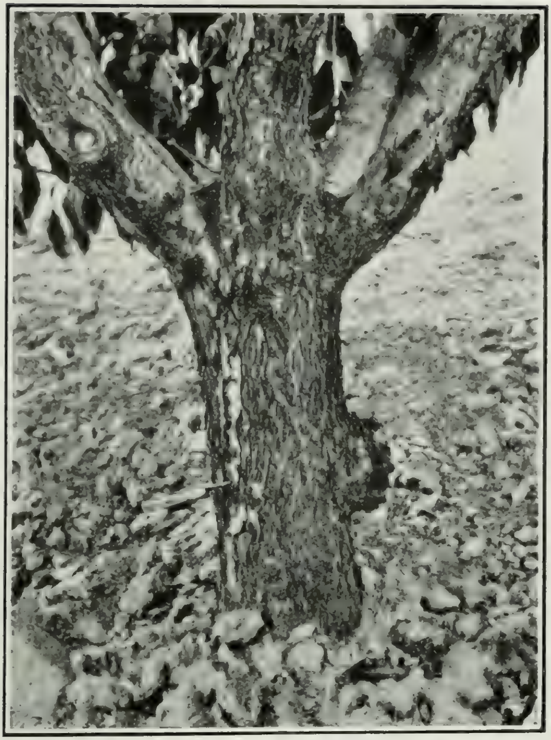


Fig. 158. ROOT-KNOT ON PEACH TREE.
Aerial tumour on the stem.

Photo by Author.

in Australian nurseries has led to the total prohibition by the Department of Agriculture of the importation of Australian nursery stock into New Zealand.*

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Root-knot is a bacterial disease caused by *Phytomonas tumefaciens*, as has been demonstrated by Smith and Townsend *(286)*. Its life-cycle is as yet imperfectly known, but it is probable that the organism overwinters in tumours and in the soil of infected nurseries, or may be spread by the roots of plants used for root-grafting if infected with the hairy-root condition. In the case of infection of the young tree from the soil, the organism enters through wounds in the root or crown formed during root-grafting, or during wrenching and cultivation. It would appear that the organism is carried through the soil to such injured surfaces by soil-water or by insects. Here it migrates to living cells by means of flagella, with which it is provided. It does not kill the cells, but stimulates them to rapid proliferation, with the result that a tumour or the "hairy-root" condition is produced.

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* This regulation has since been revoked by Order-in-Council Notice, No. Ag. 2414, *N.Z. Gazette*, No. 62, 25th Sept., 1924.

So rapidly are the tumours produced under favourable conditions that they may be visible on the fourth day after cultures of the organism have been inoculated into soft tissues; in woody tissues growth is considerably slower.

In the tumour the organism may live for many seasons, slowly multiplying and stimulating the host tissues to further growth in the diseased region, with the result that perennial tumours may attain to a very large size.

When infected nursery stock is removed from the soil, certain of these tumours may remain in the soil, there to infect other plants in turn. Diseased plants are sent from the nursery, and the disease is in this manner widely distributed.

It has been claimed that the disease is a highly infectious one, and that it may be transmitted from diseased to healthy trees in the same orchard. But no definite evidence is forthcoming that such a condition occurs in nature. Nevertheless, were nursery stock to be grown in soil that had previously contained infected trees, it is probable that they would become infected in turn.

CONSIDERATIONS REGARDING REMEDIAL TREATMENT.

The discussion of the life-history of the disease as given above applies to American conditions, for, so far as the author is aware, it is not known to occur in any New Zealand nursery, yet in several of the largest many infected trees have been held for one or more seasons. This leads to the question as to whether the conditions named root-knot and hairy-root present in New Zealand are caused by the specific organism *Phytobacter tumefaciens.* The evidence in favour lies in the facts that:—

(*a*) The disease known as root-knot produces two conditions (tumours and "hairy-root"), identical with similar conditions produced by the organism in America;

(*b*) It affects the same parts of the plant.

The evidence against:—

(*a*) Although repeated attempts have been made, *Phytobacter tumefaciens* has never been isolated in New Zealand from these tumours, nor, so far as the author is aware, has it been isolated from similar material in Australia.

(*b*) All attempts made by Waters to produce this condition by infecting healthy plants with portions of tumours have failed, as have inocula-

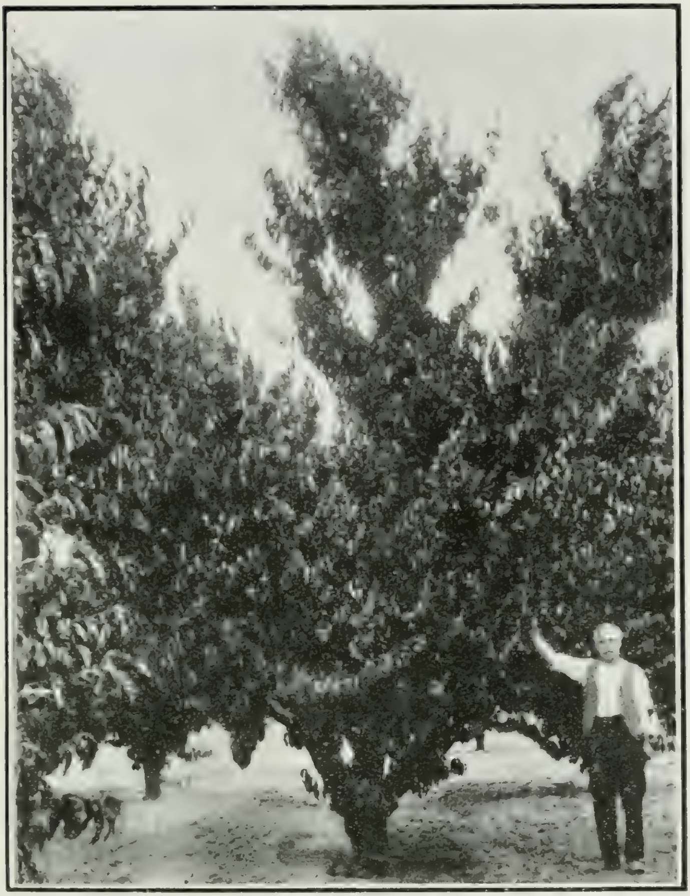

Fig. 159. ROOT-KNOT ON 18-YEAR-OLD PEACH TREE.

The tumours may be seen at the base. It is apparent that the disease has had little, if any, detrimental effect upon the growth of this tree.

Photo by Author.

tions with all organisms isolated from the tumours; yet he has been able artificially to produce tumours with a culture of the root-knot organism obtained from Dr. E. F. Smith, thus showing that the conditions for infection were suitable.

(*c*) The disease has not appeared on nursery stock grown in New Zealand nurseries, yet in many of these Australian trees affected with this root-knot condition have been held for one or more seasons.

(*d*) The disease has been known to occur in the Dominion for 24 years on both pome- and stone-fruits, yet in no single instance, in any of the orchards, has any tree been known to become infected from the soil or from diseased trees in the vicinity.

(*e*) No evidence is available showing that infected trees have made a less vigorous growth, or borne less fruit, than uninfected trees of the same age in similar soil in the same orchard.

(*f*) No case has been recorded of either young or old trees being killed by this disease.

Thus it would appear that in New Zealand root-knot has little, if any, detrimental effect on fruit-trees; and in North America opinions are divided as to its effects. Hedgecock *(157)* summarises the position as follows:—

" . . . It is apparent that the opinion of plant pathologists, with few exceptions, has been as follows:—(1) Apple crown-gall spreads rapidly in the nursery and the orchard from tree to tree. (2) It may be communicated from diseased to healthy trees by contact in bundles, etc.

"A review of the literature on the subject reveals that little has been done previously in the way of experimentation to substantiate these views as to the degree and the rapidity of the spread of the disease in the nursery and the orchard."

As a result of numerous experiments performed to prove or disprove the views expressed above, this author found that—

(*a*) There was no infection of healthy seedling plants possessing uninjured roots; but that seedlings with injured roots were readily infected, provided infection material used was taken from soft tumours.

(*b*) The use of scions from diseased trees increased the amount of disease.

(*c*) The spread of the disease from tree to tree in nursery rows is almost negligible after the first year.

(*d*) The disease is not transmitted by pruning and grafting knives, even when these had been previously used in cutting diseased roots and tumours.

(*e*) Crown-gall is communicable by contact only in wounds where fresh callus is being formed [on nursery stock]. Where trees are dormant there is little danger of communication.

(*f*) The disease is only slightly communicable in orchards. In this connection he states: " . . . The experiment certainly indicates that apple trees, when they are once established, are not in danger of becoming seriously diseased on the roots if cultivated carefully and without incurring wounds, even when every tree 9 feet away in the adjacent rows is diseased, as in the experiment. . . . The apparent effect on the growth of trees . . . was hardly perceptible. . . . These experiments prove that the effect . . . upon apple trees in the orchard has been over-rated."

In the absence of definite evidence that in New Zealand root-knot is detrimental to fruit-trees (or that it is controllable when present), no remedial treatment is suggested.

SUMMARY.

1. Root-knot is a disease of pome- and stone-fruits, and has been recorded in addition on numerous other hosts.

2. A similar condition in North America has been shown to be due to *Phytobacter tumefaciens*, but this organism has not been isolated from tumours in New Zealand.

3. It produces (*a*) tumours and (*b*) a "hairy-root" condition of the roots and crowns of the hosts.

4. It is essentially a nursery-stock disease, for trees are seldom infected once they have progressed beyond the seedling stage.

5. The disease is not known to occur in New Zealand nurseries, and is not known to be a serious trouble on established orchard trees.

6. No remedial treatment is known.

For literature references regarding this disease, see bibliography, p. 349, Nos. *39, 46, 94, 157, 191, 196, 285, 286.*

CHAPTER XXV.

STONE-FRUIT DISEASES.

(Concluded.)

(c) Physiological Diseases and Diseases of Unknown Cause.

FROST-INJURY.

Fortunately this trouble is not general, being confined to a few localities, save in certain exceptional seasons.

Late frosts may occur at the time of the setting of the fruit, resulting in a partial or total loss of the crop, or frosts during the winter months may kill buds, laterals, and even branches. Such a condition occurred in 1919 in Central Otago, where the laterals on many trees were killed back to the branches, and in some cases the branches themselves were killed. This lateral injury is not usual, however, and in the case under consideration occurred as a result of the mild and prolonged autumn experienced, for the trees continued to make wood and leaf growth until about the beginning of June, consequently when severe frosts were experienced much injury resulted.

GUMMOSIS.

This is a name applied to an exudation of gum through the bark of a tree, irrespective of the cause. It may frequently be found on the almond, apricot, cherry, nectarine, peach, and plum, as well as on citrus trees. This condition has been known for many years, and is in its distribution co-extensive with the cultivation of the hosts.

On stone-fruits in New Zealand this condition may be induced by—

(*a*) Fungous diseases:

(*b*) Larvae of boring insects (a rather uncommon condition);

(*c*) Wounds;

(*d*) Physical or physiological agencies.

For explanation of terms, see glossary, p. xi.

Several fungi are concerned in producing a gumming of the laterals, branches, and stems. Arranged in order of importance these are:—

(1) Die-back, *Clasterosporium carpophilum* (p. 252).
(2) Valsa-injury, *Valsa leucostoma* (p. 298).
(3) Brown-rot, *Sclerotinia cinerea* (p. 228).
(4) Coral-spot, *Nectria cinnabarina* (p. 245).
(5) Peach-scab, *Cladosporium carpophilum* (p. 272).

Gumming frequently follows injuries due to abrasions of the bark during cultivation, picking or pruning. In the last case gumming becomes prevalent only when trees are pruned during the wrong time of the year. This especially applies to cherry-trees, which should preferably be pruned in the spring when growth commences.

In this book the term gummosis is applied to a condition which is not caused by any of the agencies mentioned. It is a condition common on all stone-fruits, but is prevalent more especially on apricots, cherries, and peaches. With these hosts it is usually confined to one or two varieties.

APPEARANCE AND EFFECT ON THE HOSTS.

The disease is characterised by the appearance on the surface of the bark of small globules of transparent, glassy- or amber-tinted, soft gum (Fig. 161). The exudation may increase in size until it is 30 mm. or more in diameter, when it assumes a pulvinate appearance, becomes darker in colour, and considerably hardened on the surface. The gum may be produced continuously and run down the bark, but this occurs only in exceptional cases.

Another condition may be observed when affected branches are closely examined, for frequently small bark-blisters will be noticed, which, if cut into with a knife, exude gum and collapse (Fig. 160). Although not readily noticed, this is a common condition of the trouble, and is, in fact, the stage of the disease preceding gummosis, for all gum visible on the exterior is first produced in these gum-pockets.

ECONOMIC IMPORTANCE.

In general it may be said that gummosis, if slight, has little detrimental effect on the host, but where gum production is copious and lasting, then the branch, or even the whole tree, may die. Affected branches appear stunted and make little growth, and fruits produced on them are frequently small in size, and the leaves on these branches yellowish and less numerous.

It is a debatable point as to whether the disease is of sufficient merit to warrant time being spent on its elimination; this would depend on the value of the tree from a production view-point.

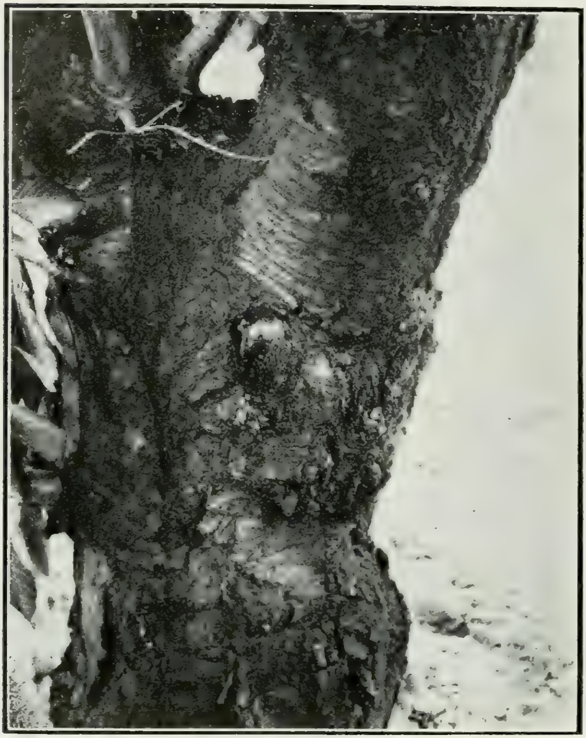

Fig. 160. GUMMOSIS OF CHERRY. Reduced.
Large gum pocket on the stem of a 22-year-old tree.

Photo by Author.

CAUSE.

Origin of the gum. Numerous theories have been propounded to account for the production of this gum which at times exudes so copiously. Butler *(73)* believed the condition to be due to hydrolysis of the walls of the embryonic wood. He stated that the primary membranes of these cells swell and gelatinise, and are rendered semi-fluid by a further absorption of water. The gelatinous mass so formed collects between the cells, forcing them apart and so producing the gum-pocket, which, by the coalescence of several affected contiguous areas, becomes of a size large enough to be seen.

Other authors believe the trouble to be due to an excess of cytase, which converts the tissues of the young wood-cells into gum. Whatever the cause, the effect on the plant is that in certain regions of the young wood-cells cavities are produced which are filled with the gum; partly by the dissolution of these wood-cells, and partly

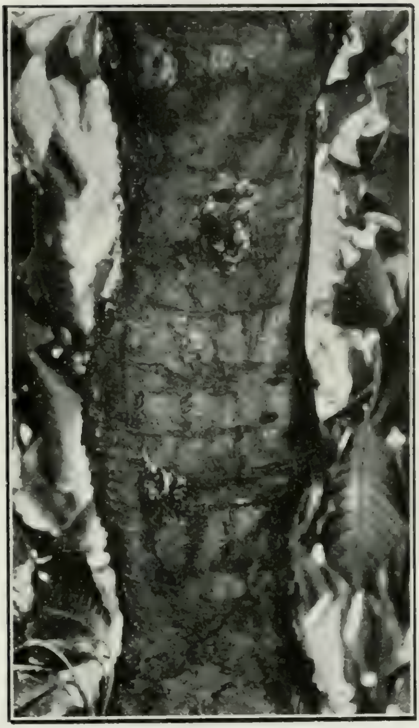

Fig. 161. GUMMOSIS OF CHERRY. Reduced.
Fresh gum exudate on a main limb.

Photo by Author.

by the swelling of the accumulating gum, the pockets are produced. When they attain to a certain size the overlying cortex becomes ruptured and the gum appears on the surface.

Conditions inducing gummosis are unknown, but numerous contributing factors have been suggested, as—

1. Excess soil-water around the roots, due to faulty drainage or faulty irrigation;
2. Defective varieties;
3. Unsuitable stocks.

REMEDIAL TREATMENT.

Although it is frequently stated that gumming is induced by excess soil-water, there would appear to be little evidence in support, for gummosis of stone-fruit trees is just as prevalent on the schist-silt soils of Central Otago, where irrigation is necessary, as elsewhere in New Zealand. The stock may influence gumming, but no data are available on this point, as gumming has been observed to occur on apricots, whether on plum, peach or apricot stocks.

Certain growers claim that by incising the bark of affected trees gumming is considerably reduced; and this is a treatment frequently recommended in Europe, except that in the latter region the incisions are placed spirally around affected branches, and not vertically, as is the case here.

Where isolated pockets occur on main branches and stems it would be advisable to cut them out, and paint over the wounds with coal tar. Such a procedure would allow of the formation of callus over the affected part.

SUMMARY.

1. Gummosis is a physiological condition affecting the branches and stems of stone-fruit trees.
2. The exciting cause is unknown, but the production of gum is due to the breaking down of wood tissues and their subsequent conversion into gum.
3. No certain remedial treatment is known, but cutting out of gum pockets and incising the bark of affected trees is claimed to decrease the trouble.

For literature references regarding this disease, see bibliography, p. 349, Nos. *65, 73, 214, 245, 288, 331.*

SOUR-SAP.

Whilst this trouble is not so prevalent on stone-fruits as on pome-fruits (see p. 216), it has on occasion been the cause of the death of a number of trees.

SPLIT-STONE.

This trouble, as its name indicates, is caused through the splitting apart of the halves of the stone. This results in the formation of a cavity in the vicinity of the pedicel; through this fungous infection may take place, the chief organisms concerned being brown-rot and rhizopus-rot. Infection is followed by rapid decay, so that fruits suffering from this trouble are seldom in a condition suitable for marketing.

The trouble is more prevalent in moist weather, rapid and unequal expansion of the fruit, with consequent splitting of the stone, resulting; but in the main it is a varietal peculiarity occurring only with certain varieties.

Where it is at all prevalent, trees should be cut back and re-worked with a more suitable variety.

CHAPTER XXVI.

Table of Citrus Diseases; Artificial Key to Citrus Diseases.

Citrus Diseases.

The following table shows at a glance which diseases, in New Zealand, occur on the various hosts included under citrus-fruits:—

HOSTS.

Page.	Lemon.	Orange.	Mandarin.	Lime.	Pomelo.
319	Bark-blotch	—	—	—	—
323	—	Citrus-anthracnose	Citrus-anthracnose	—	—
323	Citrus brown-rot	Citrus brown-rot	—	—	—
326	Citrus-verrucosis	Citrus-verrucosis	Citrus-verrucosis	Citrus-verrucosis	Citrus-verrucosis
329	Collar-rot	Collar-rot	Collar-rot	Collar-rot	Collar-rot
332	Grey-scab	Grey-scab	Grey-scab	—	—
346	Malformed fruits	Malformed fruits	—	—	—
335	Soft-rots	Soft-rots	Soft-rots	Soft-rots	Soft-rots
336	Sooty-mould	Sooty-mould	Sooty-mould	Sooty-mould	Sooty-mould
348	—	Sun-scald	Sun-scald	Sun-scald	Sun-scald
340	Wither-tip	Wither-tip	Wither-tip	—	Wither-tip

ARTIFICIAL KEY TO CITRUS-FRUIT DISEASES.

(Instructions regarding the use of the keys are to be found on p. 104).

A. CANKERS ON LATERALS AND BRANCHES.

Cankers on main branches, large, indefinite *Bark-blotch* (p. 319)
Cankers on laterals .. .. *Citrus brown-rot* (p. 323)
Cankers on stem or crown .. .. *Collar-rot* (p. 329)

B. FRUITS DECAYED, OR ROTTED.

Fructifications present.
  Fructifications grey .. .. *Botrytis-rot* (p. 182)
  Fructifications blue-green .. .. .. *Blue-mould* (p. 335)
  Fructifications black .. .. *Rhizopus-rot* (p. 296)
Fructifications absent.
  Pungent smell present .. .. *Citrus brown-rot* (p. 323)

FEEBLE

C. GENERAL DEBILITY OF THE HOST.

Leaves yellowed.		
Stem necrosed.		
Gumming copious	*Collar-rot*	(p. 329)
Gumming usually absent, or inconspicuous	*Bark-blotch*	(p. 319)
Stem apparently normal.		
Canker on branch	*Bark-blotch*	(p. 319)
Cankers absent	*Soil-trouble*	

D. GUMMING.

Gumming copious, confined to stem and crown	*Collar-rot*	(p. 329)
Gumming slight, on stem or branch	*Bark-blotch*	(p. 319)

E. LEAF-DISCOLOURATION.

Leaves yellowed	*Bark-blotch* *Collar-rot*	(p. 319) (p. 329)
Leaves covered with black mould	*Sooty-mould*	(p. 336)
Leaves brown, wilted	*Citrus brown-rot*	(p. 323)

F. SPOTS AND SCABS ON LEAF AND FRUIT.

Spots on leaves, irregular.		
Spots grey, distorting	*Citrus-verrucosis*	(p. 326)
Spots brown, raised	*Sun-scald*	(p. 348)
Spots ashy-grey, depressed	*Wither-tip*	(p. 340)
Spots on fruit.		
Spots definite, circular.		
Spots small, black	*Citrus-anthracnose*	(p. 323)
Spots large, brown, depressed	*Wither-tip*	(p. 340)
Spots, indefinite, irregular.		
Spots in form of raised scabs	*Citrus-verrucosis*	(p. 326)
Spots in form of russeted areas	*Grey-scab*	(p. 332)

G. WILTING OF LEAVES.	*Citrus brown-rot*	(p. 323)

CHAPTER XXVII.

CITRUS DISEASES.

(a) Fungous Diseases.

Commercial citrus culture is practically confined to the Auckland and northern parts of Hawke's Bay provinces, where, of recent years, numerous large citrus orchards have been planted. This phase of fruit-growing is as yet only in its infancy, for when the possibilities of the culture of these fruits in the warmer parts of New Zealand are realised, considerable areas will be planted. One of the great features of citrus fruit-trees is their comparative freedom from fungous diseases.

The Statistical Report for 1922-23 *(19)* gives the total number or citrus-trees as 18,640, or approximately 170 acres; these gave in that year a yield of 14,736 bushels.

BARK-BLOTCH, Ascochyta corticola McAlpine *(213)*.

Syn.: Lemon bark-blotch.

This disease at present is confined to three localities near Auckland city, and elsewhere has been recorded only from Victoria, in Australia. In New Zealand it has been found only on the lemon, but in Australia has been recorded in addition on the orange. The disease was noticed for the first time in 1921, when it was recorded by the author *(110)*.

APPEARANCE AND EFFECT ON THE HOST.

The disease is confined to the branches and stems, being apparently more common on the latter (Fig. 162).

The first indication of its presence is the appearance of a pale brown area, surrounded by a slightly raised margin. At this stage examination shows the bark to be dead, but quite firmly attached to the wood. The diseased zone spreads radiately outwards until a large and irregular canker is formed. This may extend for one metre or more up and down the infected branch or stem. On the branch the disease frequently extends until the branch is ringbarked, when it dies; on the stem large irregular cankers 10 cm. or more in width are formed. Finally, on old cankers the bark

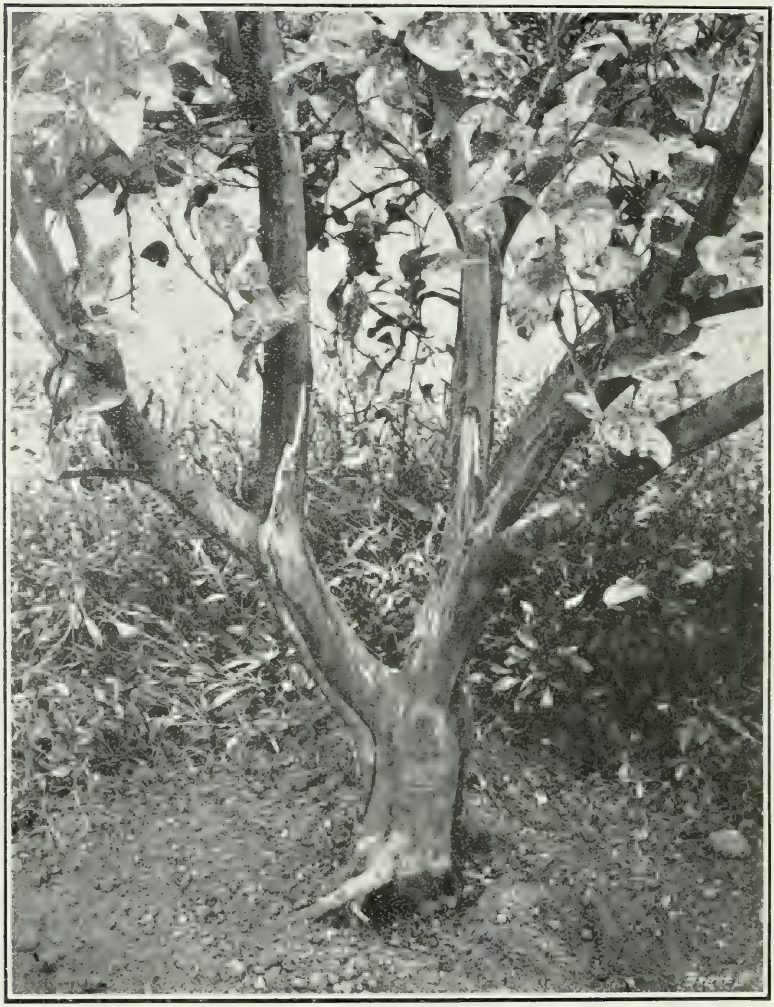

Fig. 162. BARK-BLOTCH ON LEMON TREE.

This tree has been treated for the disease; the affected area gives some idea as to the extent of infection.

Photo by Author.

begins to flake off, giving a ragged appearance to the infected portion and exposing the underlying wood.

Infection may be accompanied by gumming, but this is not a characteristic of the disease, for often this exudate does not appear until the disease has become well established, and frequently does not appear at all.

Although the disease is so difficult to detect on the branch or stem in the earlier stages, owing to the similarity in colour of infected and healthy areas, its presence is usually indicated by the behaviour of the leaves on infected trees. These, especially on infected branches, gradually become yellow, and fall prematurely.

ECONOMIC IMPORTANCE.

This disease may prove a serious one, given favourable opportunity for development, as is evidenced by the fact that in one orchard 50% of the trees were severely infected. However, it has not proved an important trouble in the country of its origin, for few, if any, additional records of its presence have been published.

As it attacks and destroys the stem and main branches of the tree, prompt remedial measures would be required, for otherwise death of the tree may result.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

The causal organism is *Ascochyta corticola,* a fungus with one spore stage in its life-cycle. It would appear that the disease is able to gain entry into the host only through injuries of some kind, such as would be caused by the flat-headed lemon-tree borer (*Aemona hirta* Broun), or through injuries formed during cultural operations, for field investigations have shown that some such injury is invariably present in a cankered zone.

Should spores be carried by insects, birds, or other agency, and one happen to alight on an injured surface, it germinates and produces an infection-hypha which penetrates to the living tissues, and there divides repeatedly to form a mycelium, the hyphae of which penetrate between and kill the cells, giving rise to the cankered condition described above. The hyphae also penetrate to and block the conduction vessels, with the result that the water supply to the leaves becomes cut off; the leaves in consequence gradually turn yellow and fall.

After a time small masses of hyphae become closely interwoven and give rise to pycnidia. These are minute, black bodies, each furnished with a short neck which protrudes on to the free surface of the bark. Each neck is pierced with a small ostiolum, through which the conidia escape. In each pycnidium are large numbers of minute, colourless, two-celled conidia (Fig. 163). When moisture is present, certain tissue at the base of each pycnidium becomes gelatinous, absorbs water, swells, and is forced out through the ostiolum as a long white tendril, in which are embedded the conidia.

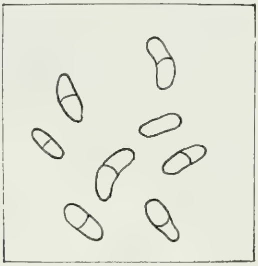

Fig. 163. ASCOCHYTA CORTICOLA.
Conidia, × 500.
Original.

Tendrils are somewhat viscid and readily attached to any object with which they come in contact, consequently they may readily be distributed by birds or insects, and as the mucilage is soluble in water, the spores may be released wherever portions of the tendril happen to be deposited. Finally the bark falls away from cankers, and carries with it the embedded pycnidia.

REMEDIAL TREATMENT.

This disease is difficult to combat owing to the fact that it is not discernible on the tree until the bark begins to fall away from the cankered areas, when it is often too late to apply any remedial treatment. Remedial treatment, therefore, would lie more in the direction of preventing further infection by the removal of sources of infection. This would necessitate the destruction by burning of all infected material, particularly of bark from cankers.

When branches have been girdled they should be removed well below the visible point of infection, and the wound thus formed painted over with coal tar. Lesions on the stem, when noticeable, should be cut out, all discoloured tissue being removed, and the wound swabbed with the disinfectant recommended on p. 36; finally, it should be painted over with coal tar.

The citrus-grower should be warned of the presence of this or a similar disease by the yellowing and premature fall of the leaves.

SUMMARY.

1. Bark-blotch is a fungous disease attacking the branches and stems of the lemon and orange. It is confined to the Auckland province, and, in addition, has been recorded from Victoria.

2. The causal organism is *Ascochyta corticola*, a fungus with one spore stage in its cycle.
3. It overwinters in cankers on the branches and stems.
4. Remedial treatment consists of the removal of sources of infection, and in cutting out of cankered areas.

For literature references regarding this disease, see bibliography, p. 349, Nos. *110, 213*.

CITRUS-ANTHRACNOSE, Phoma citricarpa McAlpine *(213)*.

Syn.: Black-spot.

This disease, fortunately, has not yet been found in New Zealand, for although specimens are frequently sent into the laboratory by the port inspectors, they have all been taken from shipments of Australian fruit.

CITRUS BROWN-ROT, Pythiacystis citrophthora Smith and Smith *(289)*.

Syn.: Brown-rot gummosis; lemon brown-rot.

In New Zealand this disease is prevalent wherever the lemon is cultivated, especially in neglected orchards. It has been found here only on the lemon, but in North America *(141)* has been recorded in addition on the grape-fruit and orange, and on the almond, apple, cherry, peach, and pear. It was first recorded for New Zealand by Boucher *(50)* in 1912.

APPEARANCE AND EFFECT ON THE HOST.

On the tree the disease first becomes noticeable by the presence of small groups of dead, brown leaves, which appear in marked contrast to the olive-green of the normal leaves.

On laterals are developed small, dead, brown areas, which do not show as distinct cankers, but remain flush with the surface. On these laterals the leaves turn brown and become brittle, but remain attached.

On the fruit a greyish-brown, slightly sunken spot is produced. This rapidly spreads until the whole fruit assumes the same pallid greyish-brown colour, and becomes somewhat soft and spongy to the touch. Infected fruits emit a peculiar pungent odour, so characteristic of the disease as to provide a reliable diagnostic character.

In Florida and Cuba the disease attacks the bark of the stem, giving rise to a copious gumming *(142)*. Infection commences at ground level, and advances upward and sidewise. The bark over the infected region remains firm, but as it dries it shrinks and cracks longitudinally. Fortunately this phase of the disease is not known to occur in New Zealand.

ECONOMIC IMPORTANCE.

Severe infection may result in the loss of all fruit on the tree, for developing fruits, as well as those of mature size, are attacked. Then, too, the laterals may be killed, resulting in the loss of the greater part of the following season's fruit.

Fortunately the disease is so readily controlled as to make it negligible in any well-cared-for orchard.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

The causal organism is *Pythiacystis citrophthora,* a fungus allied to, and by certain modern mycologists placed in, the same genus to which the late-blight of potatoes *(Phytophthora infestans)* belongs.

The fungus is normally a soil one, living saprophytically on decaying vegetable matter, and is possibly widely distributed in many soils, irrespective of whether they are given over to citrus-fruit culture or not. It can thrive only in the presence of moisture, and fructifications are produced only when an excess of moisture is present. Thus, although fruit, leaves and branches may become infected, no fructifications are produced on them while they remain on the tree. If infected fruit falls to the ground and the soil is sufficiently moist, the whole fruit and surrounding soil may become covered with hyphae, bearing fructifications.

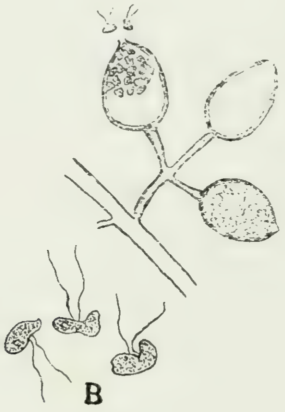

Fig. 164. PYTHIACYSTIS CITROPHTHORA.
A. Sporangia, specimen on left discharging zoospores. × 200.
B. Zoospores, showing flagella. × 500.
Original.

These fructifications are in the form of lemon-shaped, colourless sporangia, which in the presence of excess moisture rupture at the apex and discharge about 30 minute zoospores. Each zoospore possesses two ventral flagella, by means of which it moves rapidly about in the water (Fig. 164). These zoospores are the active agents in the spread of the disease, for if branches of citrus-trees happen to be close to or on the ground, they may readily be carried to the foliage by being splashed up along with soil particles in drops of water during heavy rain. If a film of water is present on the leaf, the zoospores may swim in it from place to place, and become distributed over the tree. After a time the zoospores settle down, lose their flagella, and, if conditions are favourable, germinate and each produces an infection-hypha which penetrates through the epidermis to the underlying tissues of the leaf, fruit or lateral. Here it branches repeatedly to form a mycelium, the hyphae of which penetrate and kill the tissues.

If infected fruit are placed in a case with healthy ones, the hyphae may grow out and infect the latter in turn.

REMEDIAL TREATMENT.

From a consideration of the life-cycle of this fungus it is seen that three factors are essential for its distribution to the host:—

1. The presence of excessive moisture, so that sporangia may be developed;

2. Some agency whereby zoospores produced in the sporangia on the ground may be carried to the host;

3. Direct contact of infected fruit with healthy fruit to spread the disease whilst in store.

Thus if the first two factors are eliminated, complete immunity for the host is secured.

Californian practice has shown that this may be secured by the adoption of two methods:—

1. Removal of all branches in contact with the ground;

2. Maintaining either (*a*) by cultivation a fine dry layer of soil beneath the trees, or (*b*) a cover-crop, which, by acting as a "blanket," prevents the upward carriage of zoospores by rain-splashes.

Therefore (1) cut out all growth to a height of at least 1 metre above the soil, thus preventing the zoospores from gaining a lodgment and facilitating the work of cultivating under the trees. (2) Cultivate thoroughly, stirring the ground frequently so as to form a layer of dry soil two to three inches in depth under the trees, for as the fungus can sporulate only in the presence of excess water, this dry zone prevents completely the production of zoospores. This procedure is difficult, if not impossible, to carry out in the winter months, owing to the saturated condition of the soil, so in the late autumn sow a cover-crop (*Lotus angustissimus,* 6-8 lb. per acre, is the most suitable for this purpose) and plough under in the early summer.

If during picking any infected fruits are encountered, these should be discarded, but if the remedial treatment outlined above is adopted, there is little danger of this contingency arising.

Spraying for this disease is not feasible since it spreads most rapidly when fungicides are least effective, that is, immediately after heavy rain.

SUMMARY.

1. Citrus brown-rot is a fungus disease attacking the fruits, leaves, and laterals of the grape-fruit, lemon, and orange. In California it causes, in addition, a serious stem canker of these hosts.
2. The causal organism is *Pythiacystis citrophthora.*
3. The fungus produces sporangia only in the presence of excess moisture; from the sporangia motile zoospores are produced.
4. The disease is spread by means of the zoospores, which are carried from the soil to the host in rain-splashes.
5. Control consists of the removal of all host branches and leaves to a height of 1 metre above the surface of the soil; and (*a*) cultivating to obtain a fine surface tilth, or (*b*) cover-cropping.

For literature references regarding this disease, see bibliography, p. 349, Nos. *50, 141, 142, 289.*

CITRUS-VERRUCOSIS, Sporotrichum Citri Butler *(130, bis).*

Syn.: Citrus-scab; grapefruit-scab; lemon-scab; sour-scab; verrucosis.

This is the most serious citrus disease with which the New Zealand grower has to contend. It infects the fruits, leaves, and laterals of the lemon, and elsewhere *(328)* has been recorded as being abundant on the calamondin, citrange, grapefruit, mandarin, shaddock, sour orange, tangelo, and tangerine, and is found occasionally on the kumquat and sweet-orange. It is widely distributed throughout the citrus-growing regions of the world, for it has been recorded from North and South America, Japan, South China, India and South Africa. The disease was first recorded for New Zealand by Kirk *(183)* in 1899.

APPEARANCE AND EFFECT ON THE HOST.

This disease infects fruit, leaves, and, less frequently, laterals. On the fruit it first appears as minute, raised, circular blisters, which shortly become pallid yellow or light brown. These lesions

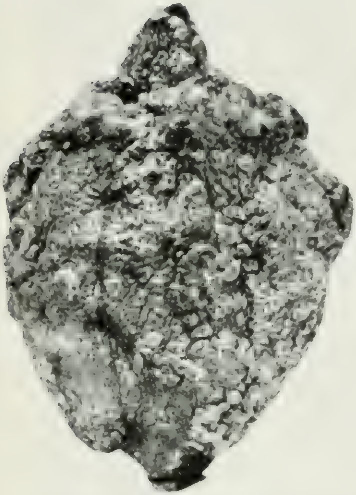

Fig. 165. CITRUS-VERRUCOSIS.
Warted condition. × ½.

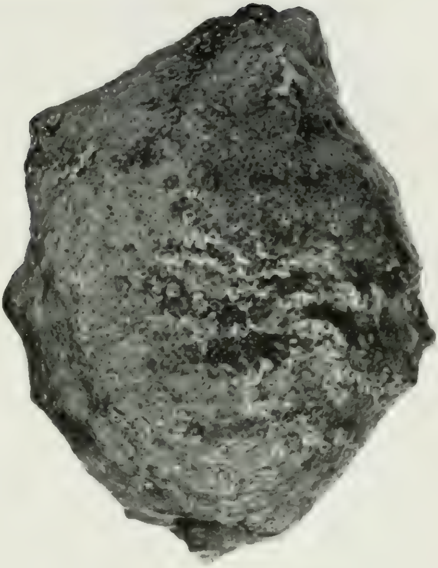

Fig. 166. CITRUS-VERRUCOSIS.
Scabbed condition. × ½.

Photos, H. Drake.

may be scattered over the fruit (Fig. 166) or may become aggregated into irregular groups, forming large scabbed areas, which in extreme cases may cover one-third of the fruit. Infected fruits become distorted, and large, irregular warts or tubercules, crowned with corky, light-coloured tissues, are formed (Fig. 165).

On the leaf similar lesions are produced, and the leaf may become distorted or blistered in the vicinity of the infected regions; or the scabbed areas may become large, flattened, and extend over a considerable portion of the lamina.

On laterals small, slightly raised, elongate scabbed areas are formed. These are of the same pallid brown colour, and are in general confined to young and tender growths.

ECONOMIC IMPORTANCE.

The disease causes little damage to the shoots and leaves, for rarely are these injured to an extent sufficient to impair their usefulness, but leaf-infection is an important factor in the perpetuation of the disease, as will be apparent when the life-history is considered. On the other hand, infected fruits are rendered unsightly by the formation of warts and scabs on their surfaces, and in cases of severe infection are frequently distorted, thus greatly lowering their market value. Moreover, on infected trees a serious reduction of the crop frequently occurs through the dropping of recently set fruits.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

This disease was long considered to be due to the fungus *Cladosporium Citri* Mass., but recent cultural and inoculation work on the part of Winston *(328)* has shown that *Cladosporium Citri* is only a saprophyte, the causal organism being a fungus which he did not name, but was later described and figured by E. J. Butler. The pathogen was first isolated by Fawcett *(139)* in 1906, but was erroneously referred by him to *C. Citri.*

The fungous hyphae penetrate between the cells of the infected tissues, and become compacted into localised mycelial masses from which arise conidiophores, bearing terminal and lateral, one-celled hyaline conidia. These conidia are carried by wind or other agency to trees in the vicinity, where, should they alight on a suitable portion of the host, and conditions prove favourable, they may germinate and produce infection-hyphae, which penetrate to the tissues and give rise to the scabbed condition described above. It would appear that the hyphae in the lesions also produce chains of chlamydospores, and that scab lesions in the spring tend to break up and flake away, thus providing an additional means of dissemination.

CONTROL.

The fungus apparently does not overwinter in lesions or infected fruit, but appears to hibernate in infected leaves. From these, it may spread by conidia, or perhaps more by means of chlamydospores (owing to the rarity of conidia in nature). Infection, according to Winston, is governed by the three factors:—

1. Suitable temperature limits;
2. Abundant moisture;
3. Host parts in a stage of development susceptible to infection.

The first is of minor importance, but the two latter factors determine the prevalence of this disease in the orchard. For leaves are susceptible to infection only when less than 15 mm. wide, fully developed leaves being immune; and fruits are immune after they have attained to a diameter of 20 mm., being most susceptible to infection immediately after petal fall. But, unless moisture is present in abundance at these stages, infection cannot occur.

As the organism spreads from lesions on mature leaves, it is essential to efficient control that the leaves be well protected until they attain a width of 15 mm.

Spraying experiments in New Zealand *(15)* have demonstrated that this disease may be held entirely in check by the use of bordeaux mixture. The schedule on p. 90 is recommended.

The oil emulsion may be omitted, but as it functions as a spreader and sticker its use is advisable in those areas in which this disease has proved difficult of control. It is also a satisfactory controllant of insect pests, so that where these are prevalent its inclusion is advisable.

SUMMARY.

1. Citrus-verrucosis is a disease attacking fruits, leaves, and laterals of citrus-trees.

2. The causal organism is *Sporotrichum Citri;* the fungus *Cladosporium Citri*, usually considered to be the cause of this disease, is now known to be saprophytic.

3. The disease hibernates in old lesions on mature leaves, and from these spreads by means of chlamydospores or conidia to developing leaves and fruits.

4. Leaves are susceptible from the time of emergence from the bud until they have attained a width of 15 mm.; fruits are susceptible from the time of their formation until they have attained a diameter of 20 mm.

5. Control is readily obtained by the use of bordeaux mixture.

For literature references regarding this disease, see bibliography, p. 349, Nos. *15, 130 bis, 139, 140, 183, 328.*

COLLAR-ROT, Cause uncertain.

Syn.: Bark-rot, foot-rot; gummosis; mal-di-gomma.

Although this disease has been known for over seventy years, its cause is still obscure. Invariably associated with it is a fungus, *Fusarium Limonis* Brio., but no experimental evidence has been brought forward in support of the widespread belief that this is the causal organism.

A similar condition in North America has been shown to be due to *Pythiacystis citrophthora*, and to *Phytophthora terrestria* (= *P. parasitica*), two related soil-fungi, the latter being prevalent on citrus fruit-trees in South America, Jamaica, and India *(143)*. The disease is co-extensive with the cultivation of *Citrus* spp., and appears to affect all cultivated species of this genus.

APPEARANCE AND EFFECT ON THE HOSTS.

As a rule the disease has become well established ere it becomes noticeable. Infection is followed by a yellowing and general unthrifty appearance of the foliage, which should indicate to the orchardist the presence of some root-trouble. This should lead to an examination of the roots and stems of affected trees, for the disease is confined to these regions. Should a gummy exudate be present at or near the crown, it is a certain indication of the presence of this or some similar trouble. The only other disease with which collar-rot is likely to be confused in New Zealand is bark-blotch (p. 319), but the flaking of the bark and general absence of gumming in the latter disease tends to separate it from the former, which is invariably accompanied by gumming. Moreover, the bark in the affected region becomes discoloured, emits a disagreeable odour, and finally becomes rotten, so that it may be removed by light pressure.

It is claimed that death of the bark with accompanying exudation of gum is the true collar-rot condition, and that *Fusarium Limonis* causes a secondary diseased condition, that is, the rotting of the bark in the diseased areas.

ECONOMIC IMPORTANCE.

Once this disease makes its appearance on a tree, the tree invariably dies unless prompt preventive measures are taken. This results in a heavy loss when bearing trees are attacked. In so far as New Zealand is concerned, it may be claimed that the disease is essentially one of nursery stock, for the author has invariably found that its attacks are either confined to young trees in the nursery, to trees but recently planted out, or to established trees in the vicinity of recently planted ones. In one instance, indeed, five simultaneous outbreaks of collar-rot in widely separated parts of New Zealand were all traceable to infected trees from one nursery.

CAUSE.

Field experience has shown that wet, poorly drained soils, deep planting, and the practice commonly in vogue among nurserymen of layering cuttings instead of budding plants on seedling stocks, all favour the onset of collar-rot.

From these facts, and the fact that the disease, if taken at an early stage, can be combated, it would appear that the trouble is due to some soil fungus; but until the organism is known, no indication can be given as to the method of infection or means whereby the disease is perpetuated.

REMEDIAL TREATMENT.

Numerous field experiments performed in New Zealand and elsewhere have shown that the disease can be combated, *provided its presence is detected at an early stage.*

This treatment consists in the cutting out of infected tissues, the exposure of such treated areas to the air, and the painting of the wounds thus formed with a fungicide. All discoloured bark should be cut away with a sharp knife, the cut being made outside the point of visible infection. This zone should then be treated with some suitable fungicide; for this purpose the following have been recommended:—

Bordeaux mixture (5-4-50), bordeaux paste, bordeaux paint, benzine-asphalt, and numerous other coal tar derivatives and proprietary compounds. Apparently one of the most efficient is bordeaux paste (p. 73). This should be applied with a stiff brush, after all diseased tissues have been cut away. When the treated area is seen to be forming callus, and gumming has ceased, the paste should be removed (a stiff brush will accomplish this) and the wound painted over with coal tar. The author would recommend as an alternative that the compound given on p. 36 be used.

Attention should be paid to drainage, and the crowns of affected trees should be exposed to the air for some months.

Frequently the question of resistant stocks is brought up in this connection. American experience has shown that the sour orange is the most resistant, the rough lemon slightly less so *(142)*.

SUMMARY.

1. Collar-rot is a disease attacking the stem, crown and upper portions of the roots of citrus-trees.

2. The causal organism is unknown, but it is probable that a similar condition is caused by more than one fungus.

3. Poorly drained soils, too deep planting, and layering, are contributory factors.

4. Remedial treatment consists of drainage; exposing the crown to the air by removing soil around the base of the tree; cutting out of infected tissues and painting this treated area with some suitable fungicide.

5. Sour orange is the most resistant stock that can be used; rough lemon is also used, but is slightly less resistant.

For literature references regarding this disease, see bibliography, p. 349, Nos. *142, 143, 144, 213, 247.*

GREY-SCAB, Gloeosporium Limetticolum Clausen *(87)*.

On orange and lemon fruits grown in New Zealand may frequently be noticed a grey scab covering part of the fruit, but present more especially near the stem end; this invariably has been referred to *Sporodesmium griseum* McAlp. *(213)*, a fungus which has not been found on New Zealand grown fruits.

Recently the author, as the result of numerous cultures, found that associated with this condition was a fungus, which agreed morphologically with the species *Gloeosporium Limetticolum.* Although no inoculation work has been performed, it is believed that grey-scab, in New Zealand at least, is due to this species, as invariably it appeared in cultures made from young or old lesions on fruit, leaf, or lateral. It has been found on the lemon, mandarin, and orange, and the same species has in North America been found to cause a wither-tip condition of the lime. As the disease is an uncommon one, it will only be briefly discussed here.

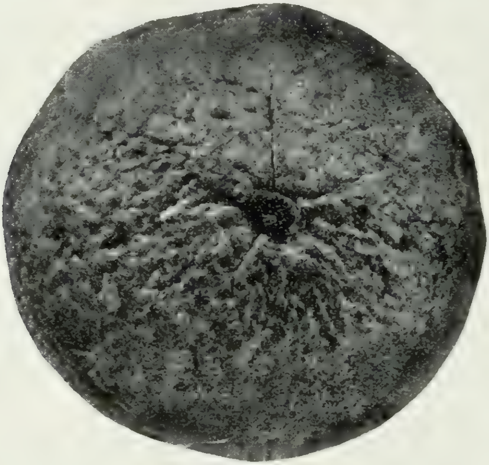

Fig. 167. GREY-SCAB ON THE FRUIT OF THE ORANGE. × ⅔.
Note that scabbed area is more abundant around the stem-end. This phase closely resembles thrips injury.

Photo, H. Drake.

APPEARANCE AND EFFECT UPON THE HOSTS.

Grey-scab attacks the fruit, leaf, and shoot. On the fruit it becomes noticeable first as a pallid-grey, slightly polished area (Fig. 167), which may range in size from 2 mm. to 20 mm. or more. At this stage it resembles closely thrips injury, but differs in not possessing the peculiar "silvered" appearance so characteristic of this trouble. Later, the affected areas become traversed by numerous slight fissures arranged in an areolate manner (Fig. 169).

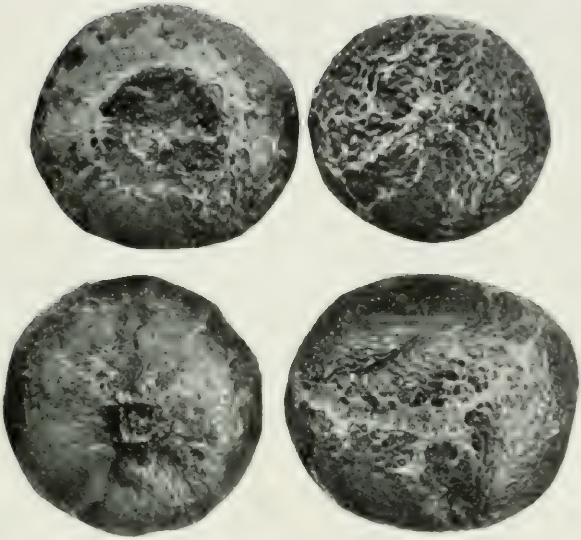

Fig. 168. GREY-SCAB ON MANDARIN FRUITS. × ½.

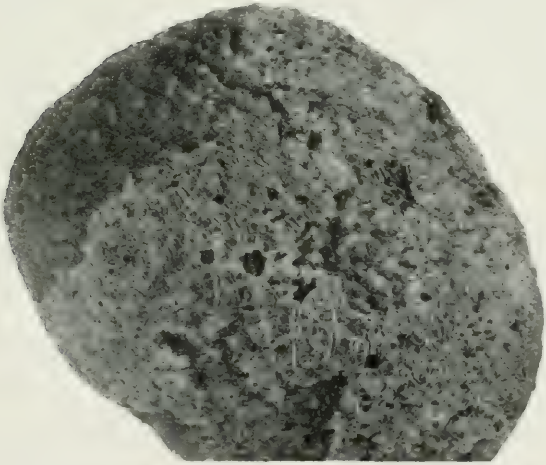

Fig. 169. GREY-SCAB ON ORANGE FRUIT. × 3.
Later stage, showing areolate markings.

Photos. H. Drake.

The grey colour and fissured appearance appear in marked contrast to the bright orange colour of the fruit. It frequently is found associated with citrus-verrucosis.

On leaves it forms small, irregular, grey, scabbed areas. These are somewhat raised above the normal leaf surface, and are surrounded by a purplish margin. This condition is so rare as to be negligible.

On laterals grey areas, up to 5 cm. or more in length, are produced. These lesions are similar in appearance to those on the leaf, save that they cover a much larger surface.

The disease tends to lower the market value of infected fruits by forming on their surfaces unsightly scabbed areas. Other than this it appears to have little effect upon the host. Where fruit infection is at all severe, it would be advisable to thin out excessive wood growth and spray according to the schedule for citrus-verrucosis, p. 90.

For literature references regarding this disease, see bibliography, p. 349, Nos. *87*, *213*.

CHAPTER XXVIII.

CITRUS DISEASES.

(*Continued.*)

(*a*) *Fungous Diseases.*—Concluded.

SOFT- AND STORAGE-ROTS.

The following are the only soft-rots that have become noticeable in New Zealand:—

1. Blue-mould, *Penicillium italicum* Wehm. and *Penicillium digitatum* (Fr.) Sacc.
2. Wither-tip, *Glomerella cingulata* (Stonemn.) Sp. et v. Schr.
3. Rhizopus-rot, *Rhizopus nigricans* Ehr.
4. Botrytis-rot, *Botrytis cinerea* Pers.
5. Citrus brown-rot, *Pythiacystis citrophthora* Sm. et Sm.

Blue-moulds (pp. 178; 296) are capable of penetrating fruits only through skin injuries caused by faulty handling in picking or during grading and packing. A fruitful source of blue-mould infection is the practice of including windfalls with the sound fruit. Windfalls are invariably punctured or bruised, and on this account should not be included in fruits intended for long distance transmission, or, in the case of lemons, for sweating. In this last operation lemons should be sweated in a well-ventilated shed, and all fruits showing signs of injury culled before being placed on the benches.

The foregoing applies equally to rhizopus-rot and botrytis-rot, for these fungi cannot penetrate the uninjured skin.

Citrus brown-rot is most economically controlled in the orchard and where the remedial treatment set forth in p. 325 is practised, should give no trouble in store or in transit.

Wither-tip infection occurs as a rule in the orchard, so that where remedial treatment for this disease is practised (p. 90) it should give no trouble in the store. All fruits showing the presence of the disease should be rigidly excluded, preferably during picking.

For literature references regarding soft-rots, see bibliography, p. 349, Nos. *137*, *244*.

SOOTY-MOULD, Capnodium citricolum McAlpine *(212)*.

This, as its common name implies, is a black mould which disfigures the fruit and leaves, and where prevalent gives to affected trees an appearance as if dusted with soot.

The mould appears as a thin, olivaceous or dusky-brown film over leaves, fruits and shoots (Figs. 170-171). It is entirely superficial, and is readily scraped from the surface. In certain localities elsewhere it is so prevalent that special washing machinery has been devised for its removal. Apart from the unsightly appearance it gives to affected fruits and trees, it does little damage, for it does not attack the host, but appears as a thin crustose film on the surface of the affected portions.

Its occurrence on the host is governed entirely by the presence of certain insect pests, as, for example, black-scale, *Saissetia oleae* (= *Lecanium oleae*) and cottony-cushiony scale, *Icerya purchasi,* for sooty-mould is found to subsist entirely on a certain sugary secretion, the so-called "honey-dew," exuded by these insects. When these insects are absent, sooty-mould is also absent.

The scales invariably are attached to the under-side of the leaves, close to the mid-rib, and exude this excretion from a special organ. The exudate falls on portions of the plant below the insect, coating them as with a film of varnish. In this, the spores of sooty-mould germinate and give rise to a copious mycelium, which, being dark in colour, lends to the affected leaf its characteristic appearance. The mycelium lives only in this film, and does not send hyphae into the tissues. From the upper surface are produced the various fructifications of the fungus, but as these are of no significance in a discussion of this disease, they need not be dealt with further. Obviously the treatment for sooty-mould lies in the destruction of the scales. This is usually accomplished by various spray applications, which in turn necessitates a considerable thinning out of woody growth, especially from the centre of the trees, to facilitate the penetration of the sprays.

For many years it has been known that species of fungi attack and destroy certain scale-insects, and this fact has been made use of to a large extent in Florida citrus plantations.

In New Zealand during the past three years a fungus has been found attacking scale-insects in the citrus orchards of Auckland

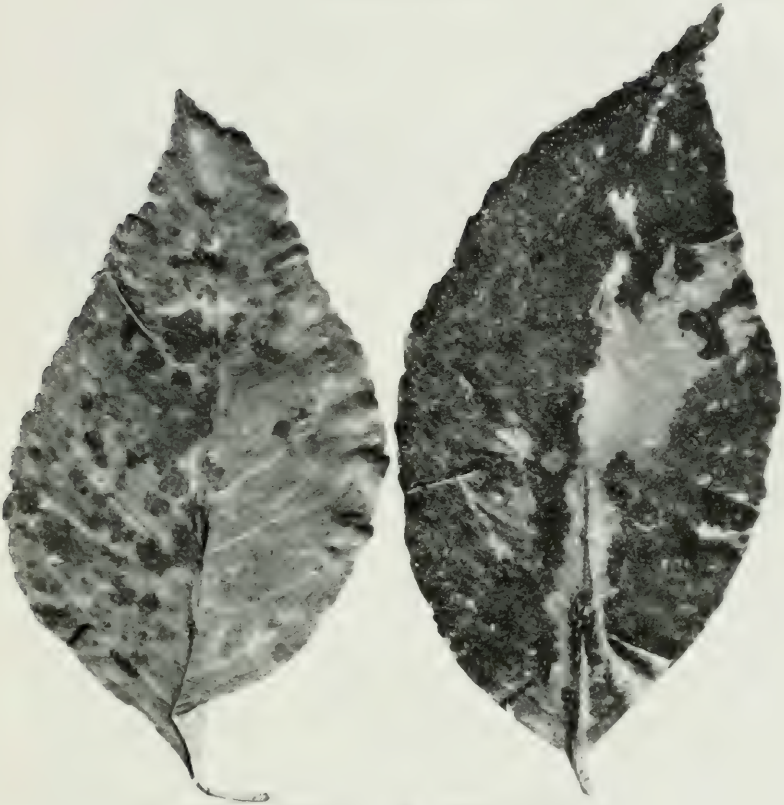

Fig. 170. SOOTY-MOULD ON LEMON LEAVES. × ½.

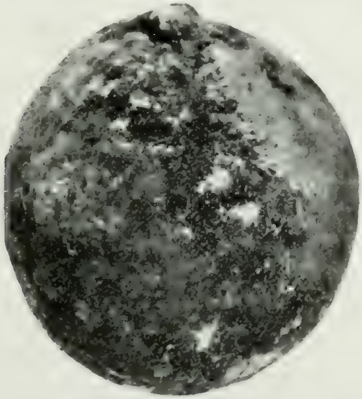

Fig. 171. SOOTY-MOULD ON LEMON FRUIT. ½.
Note the unsightly appearance its presence gives to the fruit.

Photos. H. Drake.

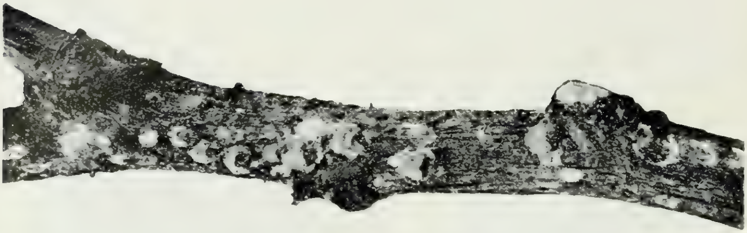

Fig. 172. SCALE INSECTS ON LEMON TREES PARASITISED BY CEPHALOSPORIUM LECANII. × 3/2.

Photo, H. Drake.

and Tauranga (Fig. 172). In certain localities, indeed, the scale has been practically exterminated by this fungus. Naturally growers have been impressed with the value of such an organism, and numerous enquiries have been made as to whether it could be utilised commercially for the purpose of keeping these insects under control, and thus obviating the need for spraying.

The control of insect pests by the use of natural enemies has long been discussed, and during recent years has formed the theme of much inaccurate writing in the popular Press—and, be it added, also in scientific periodicals. The subject is a fascinating one to the grower, the prospect of being able to control pests without labour or monetary expenditure on his part having an especial appeal.

The present position with regard to the use of fungi as insect controllants has been dealt with by Morrill and Back *(223)*. Several entomogenous fungi have been experimented with in Florida since 1896, for the control of scales and white flies. After four years' experimental work, they found that although these fungi could artificially be stabilised in a grove, their efficacy could not be increased. They have summarised the position thus:—

> " . . . As a result of the investigations . . . the authors conclude that there are at present no elements of natural control herein dealt with which can be relied upon to give satisfactory results. Under present conditions it is unquestionably more profitable to depend upon artificial remedies."

With regard to the fungus attacking citrus-scales in the Auckland province:

The fungus in question is *Cephalosporium Lecanii* Zimm. *(337)*, a species distributed throughout India, Ceylon, and Java. In Ceylon it attacks several species of *Lecanium,* and appears effectively to have controlled *Icerya purchasi (238).*

Mr. T. Petch*, in a recent letter to the author in discussing the species, states:—

> ". . . This species occurs abundantly on *Lecanium viride* in Ceylon, especially on coffee, and almost obliterates the insect regularly every monsoon, i.e., twice a year. But it is known to have been doing that since 1860, and we still have the insect abundant in the drier weather."

The same authority, in discussing the whole question of insect control by the use of fungi, states:—

> " . . . At the present day, after thirty years' trial, there is no instance of the successful control of any insect by means of fungous parasites. If entomogenous fungi already exist in a given area, practically no artificial method of increasing their efficacy is possible. If they are not present, good may result from their introduction, if local conditions are favourable to their growth; but, on the other hand, their absence would appear to indicate unfavourable conditions. It would seem that a fungus makes little progress until the insects are excessively numerous, either locally or generally, when for reasons not known an epidemic of fungus disease breaks out. And in this connection it may be noted that the apparently successful experiments in inducing a more rapid dissemination of an entomogenous fungus have usually been made during such an epidemic. . . . The problem which has yet to be solved by those who wish to control insects by means of fungi is how to create an epidemic at a time when such an epidemic would not occur naturally. The evidence indicates that it is not possible to accomplish that by the mere introduction of the fungus or by spraying spores from natural or artificial cultures. The solution of the problem probably depends in each case upon a study of the bionomics of the insect. . . ." *(238).*

The present position, then, is that control of these scales by fungous parasites is unreliable, so that the citrus grower is advised to carry out the regular spray schedule for insect control (p. 90). For if the scales are kept in check, the sooty-mould will disappear, and washing of citrus fruits before placing them on the market become unnecessary.

SUMMARY.

1. Sooty-mould is a secondary condition following the infestation of the hosts by scales and other insects.

2. The sooty-mould fungus, *Capnodium citricolum,* lives saprophytically upon the exudate or "honey-dew" of these insects.

The fungus found to be attacking scales in the Auckland province is *Cephalosporium Lecanii.* Its use as a controllant of these pests is not advocated, as partial success only will be achieved.

4. The remedial treatment recommended for the control of sooty-mould is the extermination of the insect pests; for this purpose the regular spray applications are recommended.

For literature references regarding this disease, see bibliography, p. 349, Nos. *212, 223, 238, 337.*

* Letter to the author, 29/1/24.

WITHER-TIP, Glomerella cingulata (Stonemn.) Spaulding and v. Schrenk *(310)*.

Syn,: *Colletotrichum gloeosporioides* Penz. *(233)*.

Anthracnose; false melanose; tear-streaking; brown-spot.

This disease, hitherto unrecorded, is prevalent throughout the citrus-growing areas of New Zealand. It has been found on the lime, lemon, "poor-man" orange, and sweet orange, and, in addition, has been recorded on the mandarin. It has been recorded from North and South America, East and West Indies, Malta, Southern Europe, and Australia.

APPEARANCE AND EFFECT UPON THE HOSTS.

This disease causes a serious die-back condition of shoots, hence its common name, wither-tip; but it is not confined to the shoots, for it forms depressed brown spots on the fruits, irregular dead spots in the leaves, and a shedding of blossoms and immature fruits.

On an infected tree numerous dead laterals, and even terminal shoots, may be observed scattered over the tree, this condition being accompanied by yellowing and premature shedding of the leaves. In fact, infected trees invariably present an impoverished and stunted appearance and frequently prematurely shed their fruit.

On the leaves irregular dead spots, 3-20 mm. in diameter, are produced. These may become confluent and cover the greater part of the leaf, but as a rule they are confined to the margin or tip of the leaf. In colour the spots may be yellow or brown, or, as frequently happens, they may weather to an ashy-grey.

On the fruit the disease produces two characteristic conditions, depending upon the time of infection. The first condition has usually been termed "false melanose," or "melanose," in New Zealand, but the author has not succeeded in isolating any fungus other than the *Colletotrichum* stage of *Glomerella* from such fruits. Small russeted or scabbed areas, less than 2 mm. in diameter, are produced. These may be scattered over the fruits, but are usually arranged in lines or loops, being more abundant at the stem end. These peculiar markings are characteristic of the trouble, and serve to separate this condition from the russet caused by *Gloeosporium Limetticolum* (p. 332), or from thrips injury. This, or a similar condition, has been attributed by McAlpine *(213)* to *Cladosporium brunneo-atrum* McAlp.

The second condition, usually termed "anthracnose," or "brown-spot," appears either on half-grown fruits in the orchard, or maturing

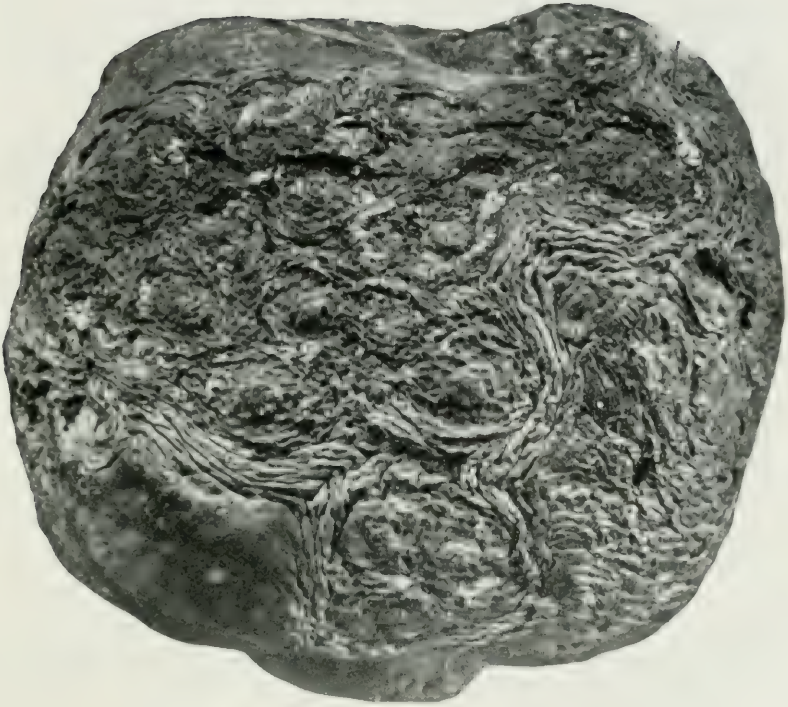

Fig. 173. WITHER-TIP ON ORANGE FRUIT. Natural size.

Photo. H. Drake.

fruits in the orchard or store. As a result of infection, small discoloured spots are formed in the epidermis. These may increase until they are 25 mm. or more in diameter. The infected portions assume a brown colour and become slightly sunken below the surface. Finally the whole diseased part becomes dingy brown or black (Fig. 173). Severe infection in the orchard usually is followed by the dropping of infected fruits. In certain cases infection may not be visible when fruits are picked, the disease developing in store or in transit.

Under certain conditions the bases of the blossom buds may be attacked, and the buds fall as a result, or if wet weather prevails at this time, the pedicels of the developing fruits may be destroyed, with consequent shedding of young fruits.

ECONOMIC IMPORTANCE.

From the foregoing it will be seen that wither-tip may under certain conditions prove a serious disease, killing the laterals, causing blossom and fruit fall, scabbing and russeting the fruits, and forming depressed spots in maturing or mature fruits in the orchard and store. In New Zealand it frequently is overlooked, but in importance it ranks second to citrus brown-rot, for it is widely distributed and has been known to cause a serious loss in certain orchards.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

The causal organism is *Glomerella cingulata,* a fungus with two spore stages in its life-cycle (see p. 110). The author has followed Shear and Wood *(280),* and considered *Colletotrichum gloeosporioides* to be a conidial stage of the above. Nevertheless, as there is a possibility that the *Colletotrichum* stage of this fungus does not belong to the cycle of *Glomerella cingulata,* it has been thought advisable to retain for this disease the name "wither-tip," rather than to merge it under bitter-rot, for should the botanical name at any time be changed, no change would be necessary with regard to the common name.

It appears to be but a weak parasite, for it attacks only those trees which have been weakened by unfavourable soil or other conditions, leading many orchardists to believe that the die-back condition was due to these unfavourable conditions, and not to any pathogen.

Spores are distributed to the leaves, fruits, and laterals by rain or other agency, where, should excess water be present, they are able to germinate. On germination a spore produces an infection-hypha which penetrates the tissues of the weakened shoot, and there gives rise to a mycelium, the hyphae of which ramify between and kill the host cells, killing the shoots and giving rise to the wither-tip condition described above. Shoots may be penetrated through their tips, the fungus gradually growing down the shoot, killing it as it advances, for on weakened trees the tips of laterals frequently succumb first.

Mycelial masses are formed beneath the epidermis of killed shoots, and from these are produced acervuli, which rupture the dead bark and appear on the surface. From these acervuli are produced masses of spores, embedded in a gelatinous matrix. This matrix is soluble in water, and during wet weather the spores are washed by rain to leaves and fruit below. The perithecia have not been found in nature, so need not be discussed here.

The russeting is caused by numerous spores being carried to the young fruits. Here they germinate and produce infection hyphæ which penetrate the cuticle, and by stimulating the host cells in the vicinity to the production of corky tissue, produce this condition. This is not followed by the penetration of the fruit, the fungus being confined to the epidermal cells. Blossom and young shoot infection occurs from spores washed on to the bearing shoots in the vicinity of the buds or fruits. Here they germinate and penetrate the tissues at the base of the bud, cutting off water supplies, with the result that the bud or fruit dies and falls away.

The anthracnose condition develops either in the orchard or after the fruit has been placed in store, but infection in the latter case occurs before the fruits are picked. Infection appears to be direct, the fungus penetrating through the injured cuticle, but the disease is noticeable only on weakened trees.

From infected shoots spores may be produced for several months, but spore production from leaves and fruits is much less common, save where the latter have been for some time in store. And it is by means of mycelium in these infected shoots that the disease overwinters.

A similar wither-tip condition has in New Zealand been found to be due to the fungus *Phoma omnivora* McAlp. *(213)*. This apparently has a very local distribution, for it has been found only on citrus-trees in the Foxton (Manawatu) district, and, as its method of control would be the same as for the preceding species, further mention is unnecessary.

CONTROL.

As this disease overwinters on dead shoots on the tree or on the ground, and as it appears to be troublesome only on unthrifty trees, it follows that if the sources of infection are removed, and steps taken to ensure a more vigorous tree, the disease may be held in check.

Therefore trees showing signs of the disease should be gone over and all dead wood removed, especial attention being paid to the removal of dead and weakly growths from the centre of the tree. The trees should then be sprayed according to the schedule on p. 90 to prevent blossom and fruit infection. Attention should be paid to drainage and to insect control.

SUMMARY.

1. Wither-tip is a fungous disease attacking leaves, buds, blossoms, laterals, and fruits.

2. The causal organism is *Glomerella cingulata,* a fungus with two spore stages in its cycle.

3. It is a weak parasite, for it is able to attack only unthrifty trees.

4. The fungus overwinters on dead wood on the tree or lying on the ground.

5. Remedial treatment consists in the removal of these sources of infection, and spraying according to the schedule recommended.

For literature references regarding this disease, see bibliography, p. 349, Nos. *69, 133, 142, 168, 213, 233, 264, 265, 280, 294, 310.*

CHAPTER XXIX.

CITRUS DISEASES.

(Continued.)

(c) Physiological Diseases and Diseases of Unknown Cause.

FROST-INJURY.

Occasionally fruits damaged by frost are found on the tree. Small irregular spots, scattered over the surface of the fruit, are formed. The cortical layer is killed beneath these spots, with the result that as the fruit increases in size, cracks are formed in the damaged region (Fig. 174).

Such fruits are subject to attack from soft-rots, and should not, on this account, be included in lines intended for storage.

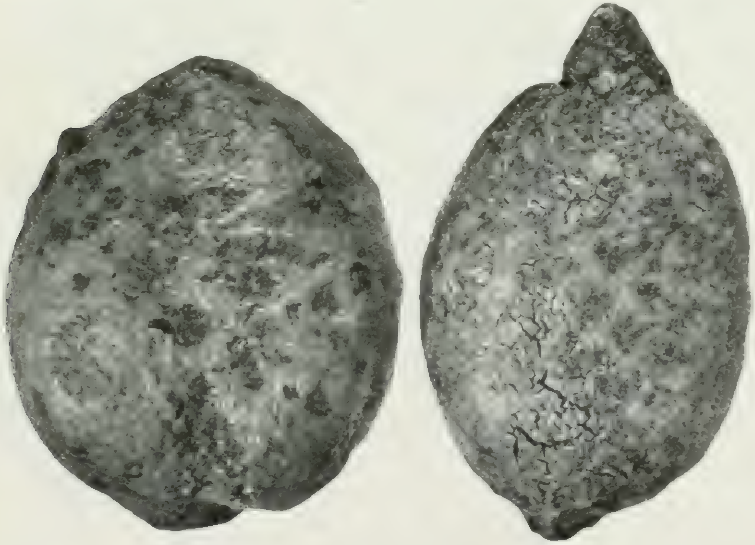

Fig. 174. FROST-INJURY ON LEMON FRUITS. × ⅔.
Photo. H. Drake.

GUMMOSIS.

This trouble is dealt with more fully under stone-fruits (see p. 312).

All cases of gumming of citrus-trees investigated by the author have been referable to one or other of the following diseases:—

1. Insect injury (borers);
2. Collar-rot (see p. 329);
3. Bark-blotch, *Ascochyta corticola* (see p. 319).

No. 1 is outside the province of this book; No. 2 is the prevalent condition, and although usually attributed to *Fusarium Limonis*, will probably prove to be due to *Pythiacystis citrophthora* (p. 323) or *Phytophthora parasitica;* No. 3, frequently, but not invariably induces gumming, especially on young branches.

MALFORMED FRUITS.

Occasionally on lemon-trees are found fruits similar in appearance to the accompanying illustrations (Figs. 175-176).

This malformation is due to the conversion of certain of the floral parts into pulp cells and cortex (p. 24).

The trouble would appear to be due to a defective strain, for when buds are taken from a tree affected with this trouble, the resultant plants frequently develop a similar condition.

When such fruits are at all numerous on a tree, it would be advisable to re-work with buds from a non-affected tree.

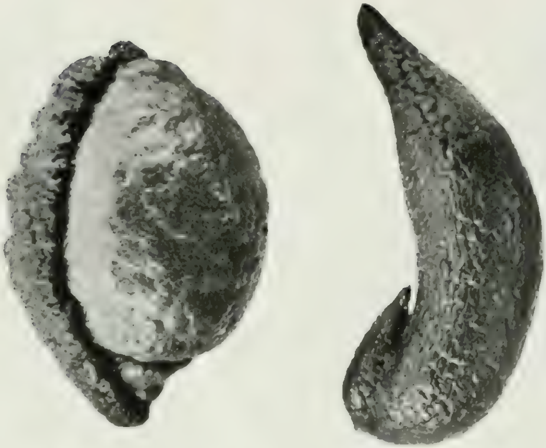

Fig. 175. MALFORMED LEMON FRUITS. × ½.

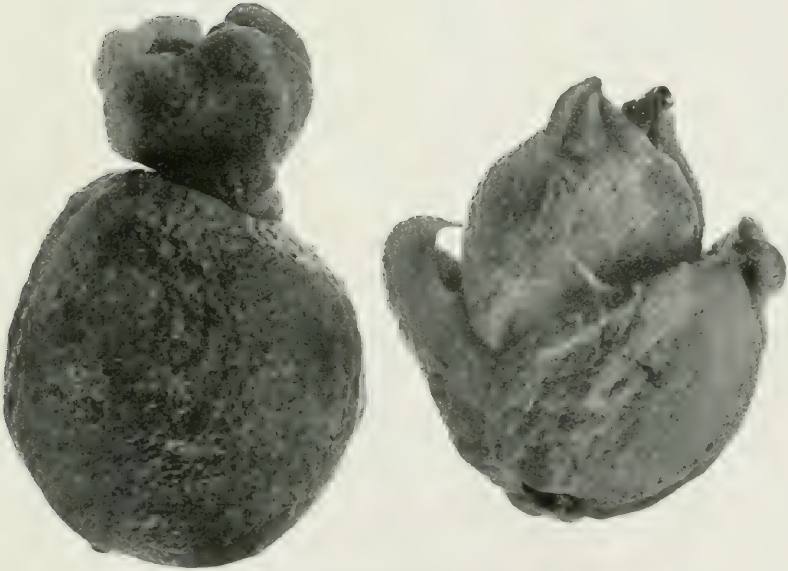

Fig. 176. MALFORMED FRUITS OF THE LEMON. × ½.

In the specimen on the left the receptacle (of the flower) has persisted and become succulent; in the specimen on the right the stamens have persisted and become succulent.

Photos. H. Drake.

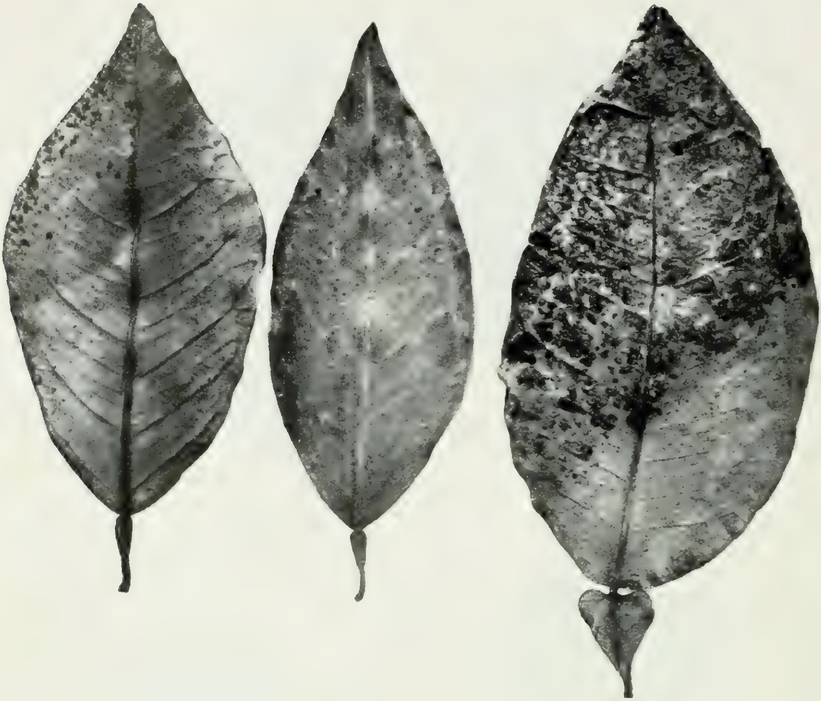

Fig. 177. SUN-SCALD ON CITRUS LEAVES. × ⅗.
Photo, H. Drake.

SUN-SCALD.

On citrus leaves one occasionally finds reddish-brown scabbed areas, as in the accompanying illustration (Fig. 177). The surface of this area is raised slightly above the normal leaf surface, and appears as if varnished. Sections show these areas to be filled with a gummous substance. It is claimed that this condition is due to sun-scald *(294)*. The trouble is confined to the under-surface, and appears to be prevalent on certain varieties of grape-fruit, mandarin and sweet orange. Its effect upon the leaf is insignificant.

FUNGOUS DISEASES OF FRUIT-TREES

BIBLIOGRAPHY.

All papers published in Scientific periodicals within New Zealand and dealing with fruit-tree diseases are included here; but only those foreign ones which have been referred to in the text are included, for a complete bibliography would run to many hundreds of pages. All names are arranged in alphabetical order, and are preceded by a reference number which, in the text, refers to the author in question.

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COMBINED HOST AND FUNGUS INDEX.

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